ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING

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Dedicated

to

my Family,

friends

&

Teachers

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ABBREVIATIONS

NIRS	Near Infra Red Spectroscopy
FLIR	Forward Looking Infra Red
ICGF	Indo Cyanine Green Fluorescence
ECG	ELECTROCARDIOGRAM
Tc	Technetium
CHI	Contrast harmonic ultrasound imaging
MRI	Magnetic Resonance Imaging
IRT	Infrared Thermography
ETI	Enhanced Thermal Imaging
LSCI	Laser Speckle Contrast Imaging
DIRT	Dynamic Infrared Thermography
DIEP	Deep Inferior Epigastric Perforator
CTA	Computed Tomographic Angiography
SPSS	Statistical Package ForSocial Science
ALT	Antero Lateral Thigh

ABSTRACT

Introduction: For flap survival, immediate intervention increases salvage rate. Clinical assessment is considered the gold standard method but it depends on the clinical experience of the health care worker. Among the new tools, the use of smartphone thermal imaging is a more objective, convinient as well as a contactless and affordable method of flap monitoring

Aim of Study: To determine the role of smartphone thermal imaging camera in monitoring of flap in the post operative period.

Materials & Methods: A prospective study was conducted on 70 patients who underwent flap surgery (both pedicled and free flap) in Department of Plastic and Reconstructive Surgery, Dayanand medical college and Hospital, Ludhiana from October,2022 to february 2024. After flap surgery, the thermal image using FLIR smartphone camera was taken at 0,1,3,6,12,24 and 48 hours after surgery where 0 is immediately post operative time. The image was also obtained whenever flap showed any signs of vascular compromise in between these time intervals. Two groups were made :

Group1: Flaps with no post operative complications

Group2: Flap with post operative complications (signs of vascular compromise, necrosis, need of any surgical intervention).

Flap vascularity was assessed by temperature gradient colour coding of thermal image taking the clinical assessment as gold standard. Sensitivity and specificity of the thermal camera was calculated.

Results: Out of 70 flaps, 63 flaps survived with success rate of 92%. Of 7 complicated flaps, 5 developed flap failure. The diagnostic accuracy of FLIR camera came out to be 91.43%, with specificity of 93.65%. The sensitivity of FLIR camera was 71.43 %

Conclusions: The results suggest that inspite of having a lower sensitivity, FLIR thermal imaging camera has high specificity and diagnostic accuracy .To conclude, smartphone thermal imaging camera has emerged as a useful tool for the early detection and management of vascular compromise in flap surgeries, special when used as an adjunct to clinical monitoring.

Keywords: Flaps, FLIR camera, Thermal imaging

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INTRODUCTION

Flap surgery forms a critical component of reconstructive plastic surgery, involving the transfer of living tissue along with its blood supply from one part of the body to another. The goal is to repair defects caused by trauma, cancer resection, congenital anomalies, or other conditions that result in significant tissue loss. Flaps can be categorized based on their blood supply into local, regional, and free flaps, each with distinct advantages and specific indications[1].

The success of flap surgery is heavily dependent on the viability of the transferred tissue. Ensuring adequate blood supply to the flap is crucial, as any compromise can lead to ischemia and necrosis, resulting in partial or complete flap loss. This can lead to severe complications, including infection, delayed healing, and the need for additional surgical interventions. Therefore, meticulous monitoring of flap perfusion in the postoperative period is essential to identify and address vascular compromise promptly[2].

Traditional methods of flap monitoring include clinical assessment, handheld doppler ultrasound, laser doppler flowmetry, and near-infrared spectroscopy (NIRS)[3]. Clinical assessment involves visual inspection of color, pin prick, measurement of temperature and capillary refill. Clinical monitoring is subjective and is dependent on observer's experience Although these methods are widely used, they have limitations in terms of sensitivity, specificity, and the ability to provide continuous, objective data[4]. Handheld Doppler ultrasound allows for the detection of blood flow in the flap's vessels, but it requires a trained operator and can be time-consuming. Laser Doppler flow metry measures microvascular blood flow, offering more detailed information about tissue perfusion, yet it is limited by its point measurement nature and susceptibility to motion artifacts. NIRS provides real time, continuous monitoring of tissue oxygenation, but it can be affected by the thickness of the tissue and ambient light conditions[3,5].

Recent advancements in technology have led to the development of more sophisticated methods for flap monitoring, aiming to overcome the limitations of traditional techniques. Among these, thermal imaging has emerged as a promising non-invasive, real-time modality that provides comprehensive information about tissue perfusion and temperature changes[6]. Thermal imaging, also known as thermography, involves the use of infrared cameras to detect and visualize heat emitted from the body surface. Infrared radiation is a type of electromagnetic radiation with longer wavelengths than visible light, making it invisible to the human eye but detectable by specialized sensors. Thermal cameras capture this radiation and convert into an image, known as a thermogram, where different temperatures are represented by varying colors[7].

The concept of thermal imaging dates back to the early 19th century when Sir William Herschel discovered infrared radiation[8]. However, it was not until the mid-20th century that infrared technology was developed for practical applications, initially for military and industrial purposes .The medical application of thermal imaging began in the1960s, with its potential for detecting breast cancer being one of the first explored areas. Over the years, advancements in camera sensitivity, resolution, and image processing have expanded the use of thermal imaging in various medical fields, including plastic surgery[9].

The principle behind thermal imaging is based on the stefan-Boltzmann law, which states that all objects emit radiation proportional to their temperature[10]. In the context of flap monitoring, the skin temperature reflects underlying blood flow and tissue perfusion. Healthy, well - perfused tissue emits a characteristic thermal pattern, while compromise tissue exhibits temperature changes due to altered blood flow. By capturing and analysing these thermal patterns, clinicians can assess flap viability and detect potential complications early[11].

Thermal imaging offers several advantages over traditional flap monitoring methods. It is non-invasive, eliminating the risk of infection or tissue damage associated with invasive techniques [12]. The ability to capture real-time, continuous data allows for dynamic assessment of

tissue perfusion, providing immediate feedback on the flap's condition [6].Additionally, thermal imaging is operator-independent, reducing variability in interpretation and improving diagnostic accuracy. Furthermore, thermal imaging can be used to monitor a wide range of flap types and anatomical locations, making it versatile for various reconstructive procedures. The visual nature of thermal images facilitates easy interpretation and communication of findings among the surgical team, enhancing collaborative decision-making. These attributes make thermal imaging a valuable too in the post operative care of flap surgeries[13].

Thermal imaging has been successfully applied in various clinical scenarios within flap marking and monitoring[14]. In free flap surgeries, it aids in assessing anastomotic patency and detecting-vascular compromise early. In pedicled flaps, thermal imaging helps in evaluating the adequacy of blood flow through the pedicle and identifying potential issues such as venous congestion. The technology has also been used in perforator flap surgeries to map perforator vessels preoperatively and ensure optimal flap design. Thermal imaging can be employed both intra operatively and post operatively. Intra operative use allows for Real-time assessment of flap perfusion before finalizing the anastomosis, potentially reducing the risk of postoperative complications. Postoperative monitoring with thermal imaging provides continuous surveillance, enabling early intervention in case of compromised blood flow. The integration of thermal imaging into routine flap monitoring protocols has the potential to improve surgical outcomes and patient safety.[15]

The field of thermal imaging in flap monitoring is rapidly evolving, with ongoing research aimed at enhancing its accuracy, reliability, and clinical utility. Advances in camera technology, image processing algorithms, and machine learning hold promise for more precise and automated interpretation of thermal images[16]. The development of portable, user- friendly thermal imaging devices can facilitate widespread adoption in clinical practice. Being an objective method, pictogram can be taken by nursing staff as well and doubtful pictures

can further be sent to the operating team and compared to clinical findings. Research is also focused on combining thermal imaging with other monitoring modalities, such as ultrasound and NIRS, to provide a comprehensive assessment of flap perfusion. Multimodal monitoring approaches can leverage the strengths of each technique, offering a more robust and reliable evaluation of flap viability. Additionally, studies investigating the role of thermal imaging in different types of flaps and various patient populations can provide valuable insights into its broader applicability[17].

Despite its advantages, thermal imaging has certain limitations and challenges. The accuracy of thermal imaging can be affected by external factors such as ambient temperature, humidity, and patient movement. Variability in skin emissivity and the presence of dressings or ointments can also influence the thermal readings. Additionally, the initial cost of acquiring high-quality thermal imaging equipment can be a barrier for some healthcare facilities. Interpreting thermal images requires a thorough understanding of normal and pathological thermal patterns, necessitating specialized training for clinicians. Moreover, while thermal imaging provides valuable information about surface temperature, it does not directly measure deeper tissue perfusion, which can limit its sensitivity in certain cases. Addressing these challenges through standardized protocols improved training, and integration with other monitoring modalities can enhance the utility of thermal imaging in clinical practice.[18]

In conclusion, thermal imaging represents a significant advancement in the field of flap monitoring, offering a non-invasive, real-time, and objective method for assessing tissue perfusion. Its integration into clinical practice can enhance the early detection of vascular compromise, improve surgical outcomes, and reduce the risk of complications associated with flap surgery. While challenges remain, ongoing research and technological developments are poised to address these issues, further establishing thermal imaging as a vital tool in reconstructive plastic surgery. The following chapters of this thesis will delve deeper into the technical aspects of thermal imaging,

review the current literature on its clinical applications, present case studies, and discuss future prospects and recommendations for its integration into standard flap monitoring protocols. Through a comprehensive exploration of thermal imaging, this thesis aims to contribute to the body of knowledge in plastic surgery and promote the adoption of innovative technologies for improved patient care.

AIMS AND OBJECTIVES

To determine the role of smartphone thermal imaging camera in monitoring of flap in the post operative period.

REVIEW OF LITERATURE

Levine reviewed the anatomy and blood supply of muscle flaps, emphasizing their crucial role in reconstructive surgery. This comprehensive review explored various types of pedicled and free muscle flaps, focusing on their classification based on vascularity. Levine provided detailed explanations of the types of vascular pedicles, their function, and the implications of choosing specific muscle flaps for reconstructive surgery. The study also highlighted how the vascularity of the flap influences the success of the surgery and the importance of understanding the anatomical nuances of muscle flaps to optimize surgical outcomes [19].

Nuara et al. conducted a detailed prospective analysis focusing on 300 consecutive microvascular reconstructions. The study primarily addressed free tissue transfer techniques in facial reconstructive surgeries, providing insights into both the success rates and complications associated with these surgeries. Common complications included flap failure due to venous or arterial thrombosis, with an emphasis on the need for prompt recognition and intervention. The research also underlined the role of surgical technique in improving success rates, thus emphasizing the importance of meticulous postoperative monitoring to detect and address complications early [20].

Kroll and colleagues focused on the timing of pedicle thrombosis and its correlation with flap loss in free-tissue transfer surgeries. The study found that most incidents of pedicle thrombosis occur within the first 72 hours post-surgery, identifying this period as critical for monitoring. Early detection of thrombosis allowed for interventions that could salvage the compromised flap. The study highlighted the need for continuous monitoring within the first few days post-surgery to prevent flap loss due to vascular compromise [21].

Chen et al. investigated how the timing of vascular compromise affects the chances of salvaging free flaps. The study emphasized that early detection of vascular compromise dramatically increases the success of flap salvage. Specifically, the study showed that flaps exhibiting

signs of compromise within the first few hours of surgery had the highest salvage rates, provided that revascularization was achieved quickly. This study underlines the necessity of using reliable and accurate monitoring methods to identify vascular compromise at the earliest possible stage [22].

Roehl and Mahabir provided a practical guide to free tissue transfer, including preoperative planning, intraoperative techniques, and postoperative management. This comprehensive review also discussed various types of free flaps and their indications based on anatomical considerations. The authors stressed the importance of selecting the appropriate flap based on the defect and the donor site, alongside thorough postoperative monitoring to ensure early detection of complications such as venous or arterial insufficiency [23].

Boykot et al. conducted a nationwide survey of microsurgeons in the USA to evaluate current perioperative practices regarding free-flap anticoagulation and postoperative monitoring. The study identified a wide range of approaches to perioperative anticoagulation, with no consensus on a standard protocol. The findings emphasized that most surgeons rely on Doppler ultrasound and clinical observation as primary methods of flap monitoring. The study also highlighted the need for evidence-based protocols to standardize perioperative care and reduce flap failure rates [24].

Suchyta and Mardini reviewed the latest innovations and future directions in head and neck microsurgical reconstruction. The study highlighted emerging technologies, including robotic-assisted surgery and advanced imaging techniques like laser Doppler and indocyanine green fluorescence. The authors explored how these technologies can enhance surgical precision and improve postoperative monitoring by providing real-time data on flap perfusion. The study concluded that these innovations hold promise for improving both functional and aesthetic outcomes in complex reconstructions [25].

Kohlert and colleagues provided an in-depth review of postoperative monitoring techniques for free flaps. The study categorized monitoring methods into non-invasive (e.g., clinical observation, Doppler

ultrasound, and thermal imaging) and invasive (e.g., implantable Doppler, microdialysis). The authors emphasized the benefits and limitations of each method and recommended combining traditional clinical observation with advanced technologies to detect vascular compromise early, improving the overall flap salvage rate [26].

Vakharia and colleagues explored the use of color Doppler ultrasound in monitoring buried free flaps, particularly in facial reanimation surgeries. The study demonstrated that Doppler ultrasound provided accurate and reliable monitoring of blood flow in buried flaps, which are otherwise difficult to monitor through direct observation. This non-invasive method allowed for real-time assessment of flap perfusion, making it a valuable tool for postoperative care [27].

Swartz et al. were pioneers in using the 20-MHz ultrasonic Doppler probe to monitor microvascular anastomoses continuously. Their experimental and clinical studies demonstrated that real-time Doppler monitoring could detect early signs of vascular compromise, allowing for timely intervention to prevent flap loss. This study laid the foundation for the development of more sophisticated Doppler monitoring systems used in modern reconstructive surgeries [28].

Jones and Wiebalck introduced an EKG-interfaced photoplethysmograph for continuous monitoring of free flaps postoperatively. This device measured changes in blood volume within the flap, offering a non-invasive way to detect early signs of vascular compromise. The study found that the photoplethysmograph was highly effective in identifying blood flow abnormalities, helping to reduce the risk of flap loss through early detection [29].

Top and colleagues reviewed the use of 99mTc sestamibiscintigraphy as a tool for monitoring free muscle flaps. This nuclear imaging technique allowed for the evaluation of flap perfusion and viability, providing a non-invasive alternative to Doppler ultrasound and other traditional methods. The study concluded that 99mTc scintigraphy is particularly useful in detecting ischemia in muscle flaps, although its cost and accessibility may limit widespread use [30].

Jung et al. compared contrast harmonic ultrasound imaging (CHI) with magnetic resonance imaging (MRI) in assessing perfusion in tissue transplants. The study found that both imaging techniques were effective for monitoring blood flow and flap viability, with CHI offering real-time perfusion data and MRI providing high-resolution structural images. These techniques were shown to complement each other in providing comprehensive flap monitoring [31].

Coninckx, M. et al. explored the feasibility of using a low-cost, commercially available mobile phone thermal imaging system for monitoring free tissue transfer flaps. The researchers employed a FLIR ONE thermal imaging device, which is a low-cost attachment for smartphones, to monitor postoperative flaps in patients undergoing head and neck reconstruction surgeries. The methodology involved capturing thermal images at various postoperative stages and analyzing them for temperature changes indicative of compromised perfusion. The study also compared the effectiveness of this low-cost system with traditional monitoring methods. The results demonstrated that the FLIR ONE device could reliably detect temperature changes that correlated with flap perfusion failure. The study highlighted the feasibility of using such low-cost devices in clinical practice, particularly in resource-constrained settings where traditional monitoring methods may not be available. The researchers concluded that smartphone-based thermal imaging could serve as an effective tool for postoperative flap monitoring [32].

Luze, H. et al. (2022) evaluated the utility of thermal imaging in assessing mastectomy skin flaps during immediate reconstruction with implants. The researchers used the FLIR ONE thermal imaging device to monitor skin flap perfusion intra operatively and postoperatively in patients undergoing mastectomy and immediate reconstruction with implants. The methodology involved capturing thermal images to identify areas at risk for necrosis based on temperature gradients. The study also explored the potential of thermal imaging to reduce postoperative complications by enabling early detection of compromised perfusion. The study found that thermal imaging

effectively identified areas at risk for necrosis, allowing for timely surgical intervention. This early detection reduced the incidence of postoperative complications such as skin flap necrosis and improved overall patient outcomes. The researchers concluded that thermal imaging is a valuable tool for intra operative and postoperative monitoring in breast reconstruction surgeries [33].

Mohan, P. et al. (2024) aimed to evaluate the feasibility and accuracy of smartphone-based digital infrared thermal imaging for monitoring free flaps postoperatively. The researchers utilized a smartphone-based thermal imaging device to monitor free flaps in a clinical setting. The methodology involved comparing thermal images with clinical and biochemical monitoring methods, focusing on the accuracy of predicting vascular compromise. The study also analyzed the ease of use, cost-effectiveness, and accessibility of the smartphone-based system. The results showed that smartphone-based thermal imaging provided a reliable and accurate method for early detection of vascular compromise in free flaps. The system's portability and non-invasive nature made it particularly useful in resource-limited settings. The study concluded that smartphone-based thermal imaging could serve as a valuable adjunct to traditional monitoring techniques [34].

Rabbani, M. J. et al. (2021) aimed to evaluate the diagnostic accuracy of thermal imaging in detecting vascular insults in postoperative flaps. The study employed a thermal imaging camera to monitor postoperative flaps in a clinical setting. The methodology involved capturing thermal images at regular intervals and analyzing the temperature gradients within the flap to identify areas of vascular compromise. The results were compared to clinical outcomes to assess the accuracy of thermal imaging as a diagnostic tool. The study found that thermal imaging had a diagnostic accuracy of 96.43% in detecting vascular insults before permanent tissue damage occurred. This high accuracy rate underscored the effectiveness of thermal imaging as a non-contact, non-invasive method for postoperative flap monitoring. The researchers concluded that thermal imaging should be

considered a valuable adjunct to clinical assessment in flap monitoring [7].

Khouri et al. reviewed a large series of 600 free flaps where surface temperature recording was the main method of monitoring used, and a detailed temperature record was kept. The sensitivity of surface temperature recording was documented as 98 percent with a predictive value of 75 percent, making it a simple, inexpensive, and highly reliable technique of free-flap monitoring [35].

Kim, H. et al. (2024) conducted a study to assess the efficacy of infrared thermal imaging for detecting vascular compromise in postoperative flaps. They employed an infrared thermal camera to monitor postoperative flaps in both experimental and clinical settings. The methodology involved comparing the temperature readings of the flap with surrounding normal tissue, focusing on identifying discrepancies indicative of vascular compromise. Infrared imaging was used as a non-contact method, allowing continuous monitoring without disturbing the patient. The results demonstrated that infrared thermal imaging could accurately detect temperature differences between the flap and surrounding tissue, with early identification of potential flap failure. This allowed for timely intervention, improving patient outcomes. The study concluded that thermal imaging is a reliable tool for postoperative flap monitoring, especially in cases where traditional methods might be insufficient [36].

Çetinkaya, E. et al. (2024), in a study aimed to explore the utility of digital infrared thermal imaging in detecting flap failure in elderly patients post-laryngectomy. The researchers employed digital infrared thermal imaging to monitor neck flaps in elderly patients who underwent laryngectomy. The methodology involved capturing thermal images of the flaps and comparing the relative temperature differences with reference tissue. The study was conducted in a clinical setting, and patients were monitored closely during the postoperative period. The study found that thermal imaging effectively detected flap failure by identifying significant temperature discrepancies between the flap and the reference tissue. The early detection enabled prompt corrective

measures, which were crucial in this high-risk population. The study concluded that digital infrared thermal imaging is a valuable tool in postoperative monitoring, particularly in elderly patients with compromised vascularity [37].

Frohwitter, G. et al. (2021) demonstrated the utility of thermal imaging in monitoring a clinically non-assessable free flap in an elderly patient. They published a case report that focused on a 90-year-old woman undergoing free flap reconstruction for extensive cutaneous squamous cell carcinoma. The methodology involved continuous thermal imaging to monitor the flap's viability postoperatively. The researchers used a thermal camera to detect temperature changes that could indicate vascular compromise, which would be difficult to assess clinically due to the patient's age and condition. The study successfully utilized thermal imaging to detect early signs of flap compromise, which allowed for timely intervention and ultimately ensured the flap's survival. The results highlighted the importance of thermal imaging in scenarios where clinical assessment is challenging, particularly in elderly patients with complex medical histories [38].

P.Singla et al in their study investigated the effectiveness of infrared thermography (IRT) as a non-invasive tool for monitoring free flap surgeries, comparing it with the traditional clinical methods. The authors conducted a study involving 41 patients who underwent free flap surgery. IRT was used alongside clinical assessments to monitor flap perfusion by measuring the temperature difference (ΔT) between the flap and the surrounding skin. The results showed that IRT could detect flap compromise earlier than clinical methods, with a sensitivity of 88.6% and specificity of 98.9% when using a ΔT cutoff value of 2°C. They concluded that IRT is a quick, objective, and cost-effective method for free flap monitoring [39].

McGinnis, C. L. et al. (2023), in a study aimed to explore the application of enhanced thermal imaging (ETI) for real-time monitoring of tissue perfusion in postoperative skin flaps, concluded that ETI could accurately detect blood vessels and monitor tissue perfusion in real-time. The non-invasive nature of ETI made it a promising tool for

postoperative monitoring, as it eliminated the need for dyes or invasive procedures. The study also showed that ETI could enhance the ability of clinicians to monitor flap perfusion and detect early signs of vascular compromise. This was an experimental study using a murine model to assess the effectiveness of ETI in detecting blood vessels and monitoring tissue perfusion. The methodology involved capturing thermal images of skin flaps and analyzing them for temperature gradients indicative of blood flow. The study also compared ETI with traditional monitoring methods to evaluate its accuracy and feasibility [40].

Nelson, Z. et al. (2021) aimed to demonstrate the utility of thermal imaging in detecting flap congestion in a patient with Fitzpatrick Skin Type VI. This case report involved the use of a FLIR ONE thermal imaging device to monitor a free flap postoperatively in a patient with Fitzpatrick Skin Type VI. The methodology involved capturing thermal images at regular intervals and analyzing them for temperature changes indicative of congestion. The study also explored the challenges of using thermal imaging in patients with darker skin tones and the potential solutions to these challenges. The results demonstrated that thermal imaging could effectively detect flap congestion, even in patients with darker skin tones. The early detection allowed for timely intervention, ultimately ensuring the flap's survival. The study highlighted the importance of thermal imaging as a non-invasive tool for postoperative monitoring, particularly in patients with challenging skin types [41].

Hallock, G. (2019) assessed the effectiveness of smartphone-based thermal imaging for monitoring perforator-free flaps in various clinical settings. The study employed a smartphone-based thermal imaging system to monitor perforator-free flaps preoperatively, intraoperatively, and postoperatively. The methodology involved capturing thermal images to identify perforators, assess perfusion, and detect early signs of vascular compromise. The study also compared the effectiveness of smartphone-based thermal imaging with traditional monitoring methods. The results showed that smartphone-based thermal imaging

was an effective tool for monitoring perforator-free flaps, providing accurate and real-time information on perfusion status. The study concluded that this low-cost, portable technology could enhance surgical outcomes, particularly in resource-limited settings where traditional monitoring methods may not be available [42].

Chava et al examined the effectiveness of infrared thermography (IRT) in the planning and monitoring of microvascular flap reconstructions, particularly for head and neck cancer patients. They conducted a study over 13 months with 20 patients and demonstrated that IRT is a reliable, non-invasive tool that can aid in preoperative perforator identification, intraoperative monitoring of flap perfusion, and postoperative detection of flap compromise. The findings showed that IRT could detect early signs of vascular compromise more quickly than traditional clinical methods, allowing for timely intervention and improving surgical outcomes. Despite some limitations, such as its two-dimensional imaging they concluded that IRT was a valuable adjunct to clinical monitoring, contributing to the overall success of free-flap reconstructions.[43]

Gray, M. et al. (2021) aimed to discuss the practical applications of the FLIR ONE thermal camera in postoperative flap monitoring, particularly in reconstructive surgery. They reviewed previous research on the use of the FLIR ONE thermal camera for monitoring free flaps postoperatively. The methodology involved analyzing the effectiveness of this low-cost, commercially available device in detecting temperature changes indicative of flap viability. The study also explored the challenges and limitations of using smartphone-based thermal imaging in clinical practice. They concluded that the FLIR ONE thermal camera is a valuable tool for postoperative flap monitoring, providing accurate and timely information on flap perfusion. The study highlighted the importance of using affordable and accessible technologies like the FLIR ONE in clinical practice, particularly in resource-limited settings [44].

Hudson, T. et al. (2023) evaluated the utility of smartphone-based thermal imaging in the management and monitoring of microvascular

flap procedures. They employed a smartphone-based thermal imaging system to monitor microvascular flaps in a clinical setting. The methodology involved capturing thermal images to identify perforators and assess perfusion during and after surgery. The study also compared the accuracy of smartphone-based thermal imaging with traditional monitoring methods. They found that smartphone-based thermal imaging had a high accuracy rate (93.3%) in identifying perforators, making it a reliable tool for postoperative flap monitoring. The study concluded that smartphone thermal imaging could enhance the management of microvascular flap procedures, particularly in settings where traditional monitoring methods are not readily available [45].

Meyer, A. et al. (2020) assessed the feasibility and utility of using a low-cost smartphone thermal imaging device for monitoring microvascular free tissue transfer flaps postoperatively. They conducted a feasibility study using a smartphone thermal imaging device to monitor microvascular free tissue transfer flaps in a clinical setting. The methodology involved capturing thermal images postoperatively and analyzing them for temperature changes indicative of compromised perfusion. The study also compared the effectiveness of this low-cost device with traditional monitoring methods. The study demonstrated that the smartphone thermal imaging device could reliably detect temperature changes associated with flap perfusion failure. The study concluded that such devices are feasible and valuable for postoperative monitoring, especially in resource-limited settings where traditional monitoring methods may not be available [46].

Schulz, T. et al. (2020), in their study, explored the potential of hyperspectral imaging (HSI) for postoperative monitoring of pedicled flaps. They employed hyperspectral imaging to monitor pedicled flaps in a clinical setting. The methodology involved capturing hyperspectral images to assess tissue perfusion based on color changes and blood flow indices. The study also compared the effectiveness of HSI with traditional monitoring methods to evaluate its accuracy and feasibility. The study found that hyperspectral imaging could provide accurate and

non-invasive monitoring of flap perfusion, making it a valuable tool for postoperative care. The study concluded that HSI could enhance the ability of clinicians to monitor flap viability and detect early signs of vascular compromise [47].

Hallock, G. (2020) aimed to evaluate the use of smartphone thermal imaging for safer postoperative monitoring of propeller flaps. The researchers employed a smartphone thermal imaging device to monitor propeller flaps in a clinical setting. The methodology involved capturing thermal images to identify perforators and assess perfusion during and after surgery. The study also explored the potential of thermal imaging to reduce postoperative complications by enabling early detection of compromised perfusion. The study demonstrated that smartphone thermal imaging could provide accurate and timely information on flap perfusion, allowing for safer use of propeller flaps in clinical practice. The study concluded that smartphone thermal imaging is a valuable tool for postoperative monitoring, particularly in challenging cases [48].

Pereira, N. et al. (2020) aimed to assess the accuracy of smartphone thermography in identifying perforators for local flaps in lower extremity surgery. The researchers conducted a prospective study using smartphone thermography to identify perforators and monitor local flaps in lower extremity surgery. The methodology involved capturing thermal images preoperatively and postoperatively to assess flap viability and aid in surgical planning. The study also compared the accuracy of smartphone thermography with traditional methods. The study found that smartphone thermography had a high viability prediction accuracy, making it a valuable tool for flap design decision-making and postoperative monitoring. The study concluded that smartphone thermography could enhance surgical outcomes, particularly in lower extremity surgeries where accurate perforator mapping is crucial [49].

Han, T. et al. (2020) compared the accuracy of indocyanine green angiography, thermal imaging, and near-infrared spectroscopy in predicting tissue necrosis in a rat perforator flap model. They conducted an experimental study using a rat perforator flap model to

compare the effectiveness of three imaging techniques: indocyanine green angiography, thermal imaging, and near-infrared spectroscopy. The methodology involved monitoring flap perfusion using each technique and assessing their accuracy in predicting tissue necrosis. The study found that indocyanine green angiography was more accurate than thermal imaging and near-infrared spectroscopy in predicting tissue necrosis. However, thermal imaging still provided valuable information on flap perfusion, particularly when used in conjunction with other imaging methods. The study concluded that a multimodal approach might offer the best outcomes in flap monitoring [50].

Im, J. et al. (2020) evaluated the potential of laser speckle contrast imaging (LSCI) for non-invasive postoperative monitoring of pedicled flaps. They employed laser speckle contrast imaging to monitor pedicled skin flaps in a rat model. The methodology involved capturing LSCI images to assess blood flow changes and tissue perfusion in the flap. The study also compared the effectiveness of LSCI with traditional monitoring methods to evaluate its accuracy and feasibility. The study demonstrated that LSCI could provide accurate and non-invasive monitoring of blood flow and tissue perfusion in pedicled flaps. The study concluded that LSCI is a promising tool for postoperative flap monitoring, offering a non-invasive alternative to traditional imaging techniques [51].

Knoeddler et al compared traditional clinical (manual) monitoring methods versus modern technological solutions, such as infrared thermography, Doppler ultrasound, and implantable sensors. The study assesses the accuracy, reliability, and cost-effectiveness of these methods in detecting early signs of flap failure. It concludes that while advanced monitoring technologies offer enhanced precision and early detection, human clinical assessment remains indispensable, especially in resource-limited settings. They emphasized the integration of both man and machine for optimal outcomes in free flap surgeries[52].

Yassin et al evaluated the use of smartphone thermal imaging technology as a modality to monitor different stages of perforator flap surgery .they concluded that Smartphone thermography is a valuable, cheap, rapidly employable, and objective tool not only for the design of perforator flaps, but also for the decision making intraoperatively to achieve the best surgical outcome.[53]

Thiessen et al conducted a study to assess the role of Dynamic Infrared Thermography (DIRT) as an alternative imaging modality for perforator identification. They concluded that the use of DIRT with their standardized measurement setup is a useful, non-invasive tool during breast reconstructions with free DIEP-flaps in all the phases of the reconstruction (pre-, intra- and post-operative). [54]

Czapla et al. evaluated the effectiveness of thermography in preoperative planning for tissue flap surgeries, particularly in locating perforators and assessing their efficiency. They demonstrated that the use of weak perforators increased the likelihood of flap ischemia and necrosis, while the presence of multiple perforators improved flap viability. These findings highlight the potential of thermography as a reliable tool for improving surgical outcomes in reconstructive procedures.[55]

Patel, R. et al. (2020) explored the use of thermal imaging in monitoring free flaps in head and neck reconstruction surgeries. They used thermal imaging to monitor free flaps in patients undergoing head and neck reconstruction surgeries. The methodology included capturing thermal images during and after surgery to assess flap perfusion and detect early signs of vascular compromise. The study demonstrated that thermal imaging could reliably detect compromised perfusion, allowing for early intervention and improving surgical outcomes in head and neck reconstructions [56].

Sonda et al analysed the usefulness of DIRT, CTA and hand held Doppler in preoperative planning of DIEP flaps. They concluded that DIRT is a useful tool in the preoperative planning as it is easy to use and provides reliable information about the location of perforators and the properties of angiosomes. They concluded that DIRT can be an

innovative and promising implementation of CTA and HHD techniques for preoperative perforator mapping in DIEP breast reconstruction[57].

Cruz et al conducted a study to assess the role of thermographic camera for earlt detection of vascular compromise in flap surgery on 40 patients . they concluded that use of thermographic camera can reduce detection time of vascular obstruction by several hours in microvascular free flaps. This method can be useful for early diagnosis of postoperative vascular obstruction.[58]

Nguyen, T. et al. (2022) aimed to evaluate the effectiveness of thermal imaging in monitoring flap perfusion in patients undergoing reconstructive surgery after traumatic injury. They used thermal imaging to monitor flaps in patients undergoing reconstructive surgery after traumatic injury. The methodology involved capturing thermal images at various stages of healing to assess perfusion and detect early signs of compromise. The study found that thermal imaging was an effective tool for monitoring flap perfusion in trauma patients, allowing for early intervention and reducing the risk of complications [59].

Sven weum conducted a study to analyse the efficacy of DIRT vs CTA for perforator marking in breast reconstruction and concluded that perrforators selected with DIRT have arterial Doppler sound, are clearly visible on CTA and provide adequate perfusion for DIEP in breast reconstruction.[60]

S ismail et al conducted a study to dertermine the the diagnostic accuracy of thermal imaging using smartphone for preoperative perforator mapping in perforator-based flaps and concluded that thermal imaging is an useful adjunct for flap marking preoperatively .[61]

In 2015, Maren et al. conducted a study on the monitoring of free flaps for oropharyngeal reconstruction using thermal imaging. They calculated the temperature differences and examined the thermal images in preoperative, intraoperative (both pre-anastomosis and post-anastomosis), and postoperative courses, and found significant temperature differences before and after vascular anastomosis of the flap. They used an endoscopic infrared thermographic camera and

relied more on temperature differences than the thermal image itself [62].

Romero et al., in their study explored the efficacy of various postoperative monitoring techniques for free flap surgeries, with a particular focus on the application of thermal imaging. The researchers employed thermal imaging devices to assess flap viability, investigating its ability to detect early signs of vascular compromise such as arterial or venous insufficiency. Their findings highlighted the accuracy of thermal imaging in identifying perfusion-related issues, showing it to be a non-invasive and efficient method for real-time monitoring. The study concluded that while thermal imaging is valuable on its own, its diagnostic accuracy increases significantly when used in conjunction with other monitoring techniques, such as Doppler ultrasound or indocyanine green angiography.[63]

MATERIALS AND METHODS

SOURCE OF DATA

A prospective study was conducted on 70 patients who underwent flap surgery (both pedicled and free flap) in Department of Plastic and Reconstructive Surgery, Dayanand medical college and Hospital, Ludhiana from October,2022 to february 2024

METHOD OF COLLECTION OF DATA

Inclusion Criterio

All patients who-

- Gave informed consent to participate in this study
- Underwent any flap surgery with assessable skin paddle

Exclusion Criteria

- Patients who did not give consent.
- Patients with inaccessible flaps.

FLIR (FORWARD LOOKING INFRA RED) smartphone thermal imaging camera was used. After inserting the thermal imaging camera into charging port (micro- USB port) of smart phone, the phone application was selected. Camera was used to obtain thermal image of the flap.

- The instructions to obtain the thermal pictogram were followed as per the FLIR camera protocol. The viability of flap circulation was noted according to temperature gradient colour coding taking bright orange, yellow and white as well perfused while dark orange, red blue or purple as poorly perfused or non perfused areas. The pictogram was taken at 0, 1, 3, 6, 12, 24 and 48 hours after surgery where 0 was immediately post operative time. Clinical assessment which included colour of skin paddle, capillary refill, temperature, bleeding on pin prick were done at same time intervals.

Thermal pictogram was obtained whenever clinically flap showed any signs of vascular compromise.

Two groups were made:

Group1: Flaps with no post operative complications.

Group2: Flap with post operative complications (signs of vascular compromise, necrosis, need of any surgical intervention).

Decision to intervene surgically was based exclusively on clinical assessment.

OUTCOME: Flap vascularity was assessed by temperature gradient colour coding of thermal image taking the clinical assessment as gold standard. Sensitivity and specificity of the thermal camera was calculated.

Statistical Analysis (Name of the method in plan)

Continuous variables were reported as mean (standard deviation) or median (interquartile range) depending on the distribution of data and frequency (percentage). Categorical variables were described using absolute and relative frequencies and were analyzed with a X2 test. All analyses were conducted using SPSS (statistical package for the social science) SPSS 21version (SPSS Inc, Chicago, IL, USA) and were two tailed, with $P<0.05$ as the level of significance.

OBSERVATIONS AND RESULTS

This study was conducted from October 2022 to February 2024 (19 months) in the Department of Plastic and Reconstructive surgery, Dayanand Medical College and Hospital. A total of 70 patients were included.

Table 1 shows the frequency distribution of 70 cases according to age

The maximum number of patients 27 belonged to age group of 21-40 years.

Minimum age in study was 3 years, maximum age 70 years and mean age being 32.67 years.

TABLE 1: Frequency distribution of total cases (n=70) according to age range.

AGE GROUP (YEARS)	No. of cases	Percentage
< 20	8	11.4%
21-40	27	38.6%
41-60	24	34.3%
> 60	11	15.7%
Total	70	100.0%

Figure 1: Frequency distribution of total cases (n=70) according to age range.

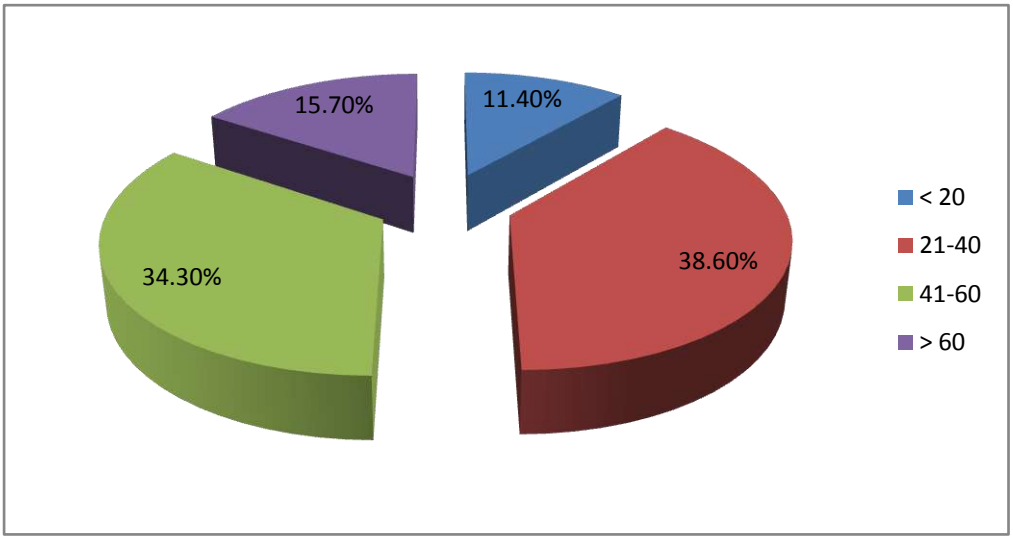


TABLE 2: Frequency distribution of total cases (n=70) according to gender

SEX	No. of cases	Percentage
FEMALE	5	7.1%
MALE	65	92.9%
Total	70	100.0%

Table 2 shows that, out of 70 patients, there were 65 males (92.9%) and 5 females(7.1%).

FIGURE 2: **Frequency distribution of total cases (n=70) according to gender**

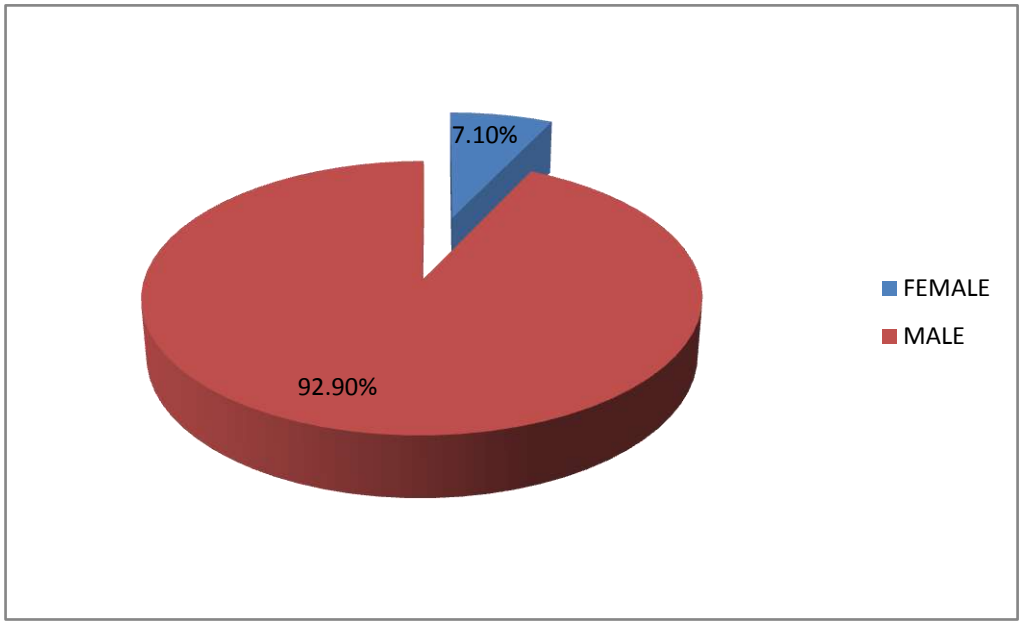


TABLE 3: Frequency distribution of total cases (n=70) according to etiology of defects needing flap coverage

ETIOLOGY	No. of cases	Percentage
INFECTION	2	2.8
PRESSURE INJURY	2	2.8
TRAUMA	32	45.71
BURNS	12	17.14
MALIGNANCY	22	31.42
TOTAL	70	100.0%

According to table no 3, the most common cause of defect requiring flap coverage was trauma, seen in 32 patients (45.71%). Malignancy was seen as the cause of defect in 22 patients (31.42%).

Figure 3: Frequency distribution of total cases (n=70) according to etiology of defects needing flap coverage`

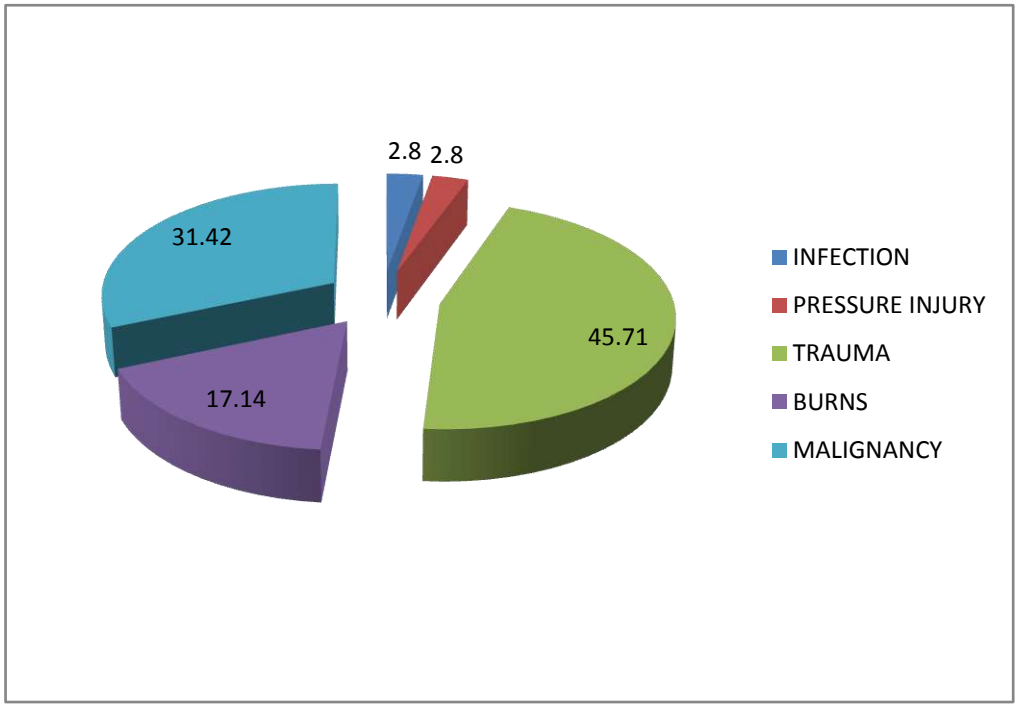


TABLE 4: Frequency distribution of total cases (n=70) according to defect site

SITE	No. of cases	Percentage
HEAD AND NECK	21	30%
FINGER	6	8.5%
FOOT	5	7.1%
HAND	14	20%
LEG	15	21.4%
NECK	1	1.4%
RIGHT CHEST WALL	1	1.4%
SACRUM	4	5.7%
SCALP AND FOREHEAD	3	4.2%
Total	70	100.0%

Table 4 shows that the most common site of flap coverage was head and neck defects (21patients), followed by leg (15 patients) and hand (14 patients).

FIGURE 4: Frequency distribution of total cases (n=70) according to defect site

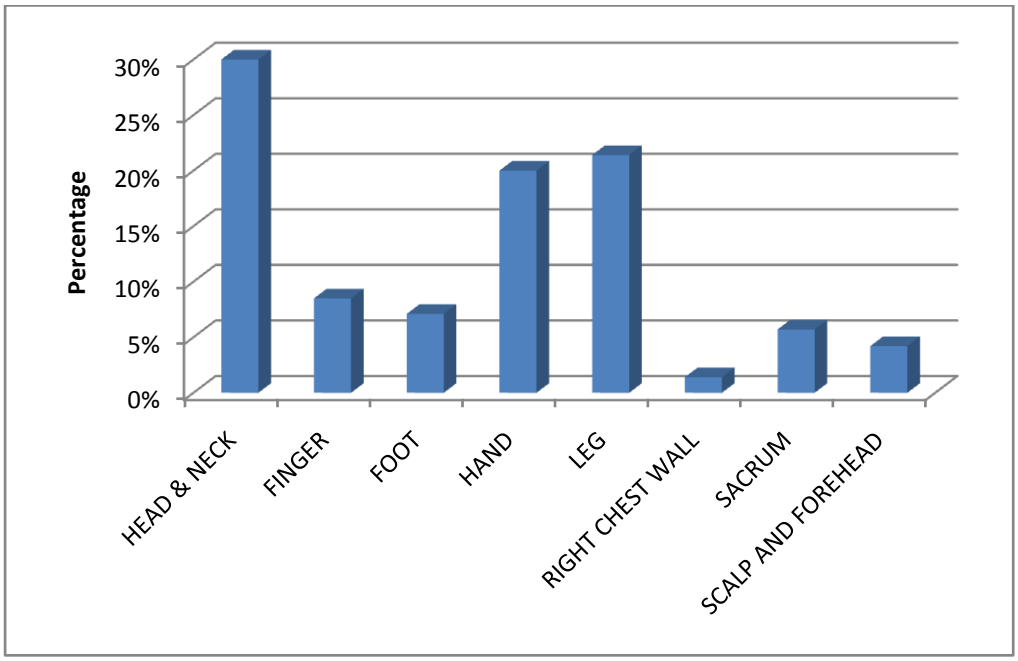


TABLE 5: Frequency distribution of types of flaps used in study cases (n = 70)

FLAP NAME	No. of cases	Percentage
FREE FLAP	21	30%
PEDICLED FLAP	49	70%
Total	70	100.0%

Table 5 shows that pedicled flap were done in 49 patients (70%) and free flaps were done in 21 patients (30%)

FIGURE 5: Frequency distribution of types of flaps used in study cases (n = 70)

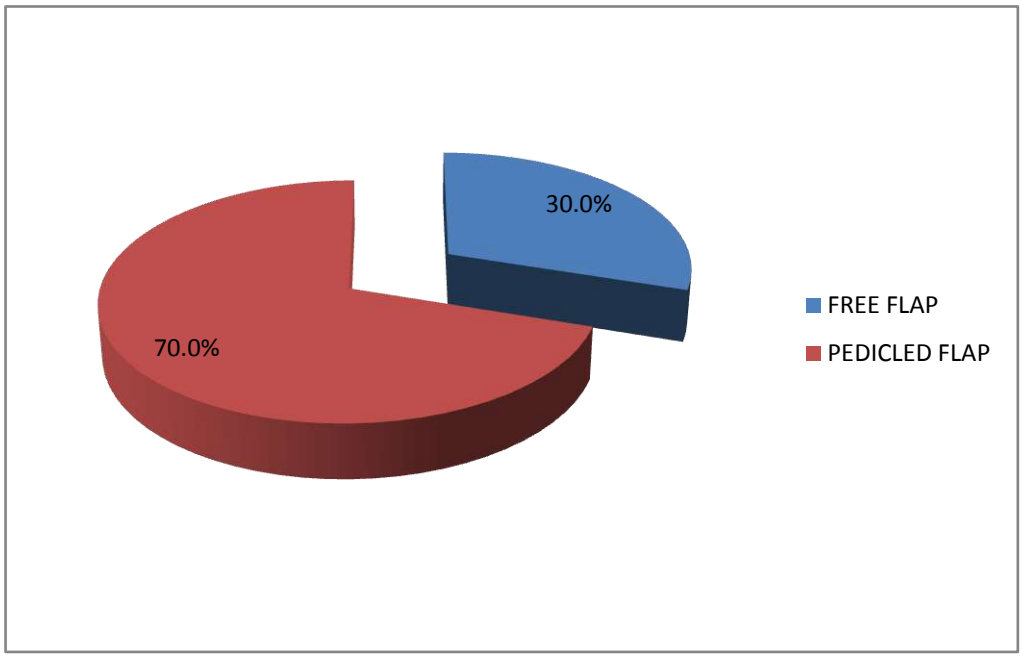


TABLE 6: Frequency distribution of total cases (n=70) according to flaps used.

FLAP NAME	No. of cases	Percentage
BIPEDICLE FLAP	1	1.4%
CROSS FINGER FLAP	4	5.7%
CROSS LEG FLAP	7	10.0%
FOREHEAD FLAP	2	2.9%
FREE ALT FLAP	7	10%
FREE LATISMIS DORSI FLAP	2	2.9%
FREE RADIAL ARTERY FOREARM FLAP	12	17.14%
GROIN FLAP	13	18.57%
V-Y ADVANCEMENT FLAP	2	2.9%
LIMBERG FLAP	3	4.3%
PECTORALIS MAJOR MYOCUTANEOUS	5	7.1%
REVERSE SURAL ARTERY FLAP	4	5.7%
THENAR FLAP	1	1.4%
TRANSPOSITION FLAP	7	10%
Total	70	100.0%

According to table 6, the most common flap performed in this study was groin flap (13 patients) followed by radial artery free forearm flap (12 cases).

Figure 6: Frequency distribution of total cases (n=70) according to flaps used.

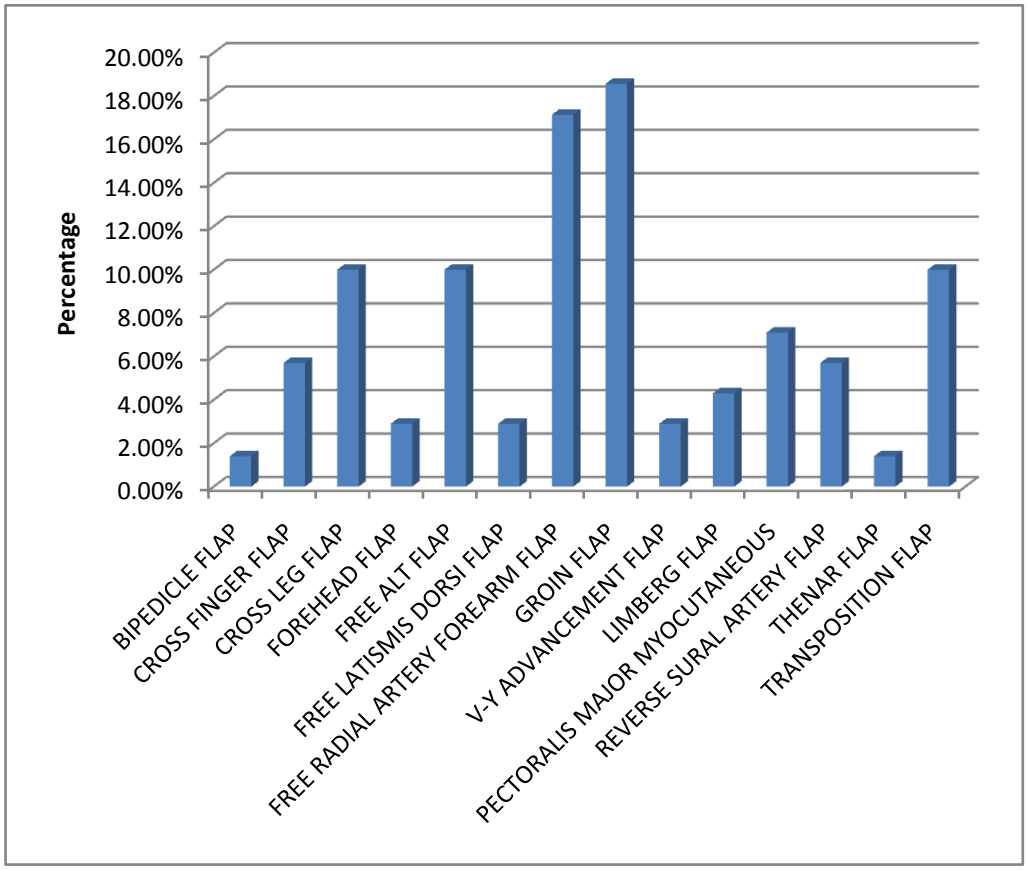


TABLE 7: Frequency distribution of total cases (n=70) according to findings on clinical examination of flaps in post operative period.

CLINICAL PARAMETERS		Time (HOURS)						
		0	**1**	**3**	**6**	**12**	**24**	**48**
A)COLOR	NORMAL	70	70	70	69	68	67	66
	BLUISH DISCOLORATION	0	0	0	1	1	2	2
	PALE DISCOLORATION	0	0	0	0	0	0	1
	MARGINAL BLACKENING	0	0	0	0	1	1	1
B)CAPILLARY REFILL	NORMAL	70	70	70	68	68	66	65
	PROLONGED	0	0	0	2	2	4	5
C)BLEED	ARTERIAL	69	69	69	67	64	63	63
	VENOUS	0	0	0	2	4	4	4
	MIXED	1	1	1	0	0	0	0
	DELAYED ARTERIAL	0	0	0	0	2	1	1
	ABSENT	0	0	0	1	0	2	2
D)TEMPERATURE	NORMAL	70	70	70	69	69	66	66
	INCREASED	0	0	0	1	1	1	0
	COLD	0	0	0	0	0	3	4

Clinical observation was done at 0hr , 1 hr , 3 hr , 6 hr , 12 hr , 24 hr and 48 hr and their color, capillary refill , bleed on pin prick and temperature were monitored and any change was noted.

At 0 hour :

- 70 flaps had normal color, capillary refill time, temperature.
- One flap having mixed pin prick.

At 1 hour:

- 70 flaps had normal color, capillary refill time, temperature.
- One flap having mixed pin prick.

At 3 hours :

- 70 flaps had normal color, capillary refill time, temperature.
- One flap having mixed pin prick.

At 6 hours :

- Bluish discolouration was seen in 1 flap.
- Capillary refill was prolonged in 2 flaps.
- Bleed was arterial in 67 flaps, venous in 2 and absent in 1 flap.
- Increased temperature seen in 1 flap.

At 12 hours

- Bluish discolouration was seen in one flap with development of marginal blackening in one flap.
- Capillary refill was prolonged in 2 flaps.
- Bleed was arterial in 64 flaps, venous in 4 and delayed arterial in 2 flaps.
- Increased temperature seen in 1 flap.

At 24 hours :

- Bluish discolouration was seen in two flaps with marginal blackening in one flap.
- Capillary refill was prolonged in 4 flaps.
- Bleed was arterial in 63 flaps, venous in 4 and delayed arterial in 1 flap and absent in 2 flaps.
- Increased temperature seen in 1 flaps and decreased temperature was seen in 3 flaps.

At 48 hours:

- Bluish discoloration seen in 2 flaps, pale color in one flap and marginal blackening seen in one flap.
- Prolonged capillary refill time seen in 5 flaps.
- Bleed on pin prick was absent in 2 flaps, delayed arterial in 1 and venous in 4 flaps.
- It was arterial in remaining 63 flaps.

Figure 7: Frequency distribution of total cases (n=70) according to findings on clinical examination of flaps in post operative period.

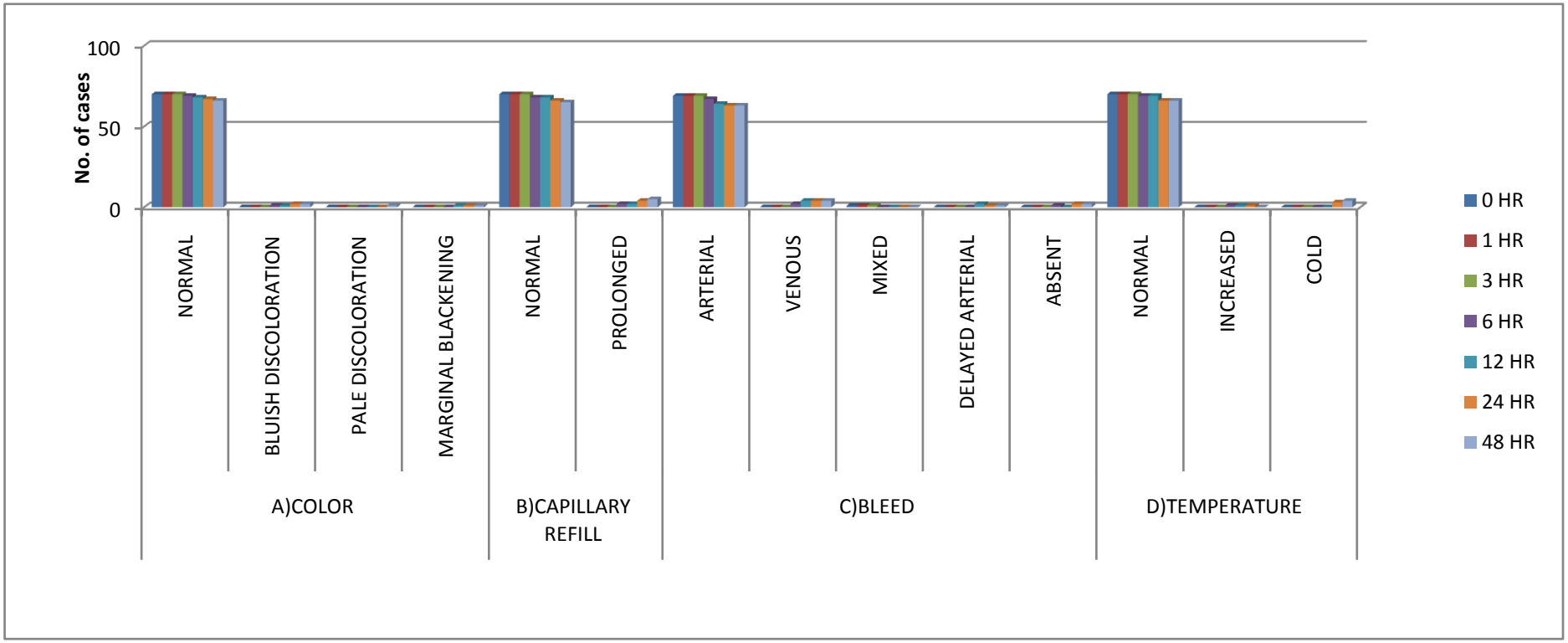


TABLE 8: Frequency distribution of total cases (n=70) according to findings on FLIR pictogram of flaps in post operative period.

FLIR PICTOGRAM	Time (HOURS)						
	0 HR	**1 hr**	**3 hr**	**6 hr**	**12 hr**	**24 hr**	**48 hr**
Normal	70	70	67	66	65	63	62
Blue spots	0	0	2	2	1	2	4
white spots	0	0	1	1	4	5	4
white and yellow spots	0	0	0	1	0	0	0
Total	70	70	70	70	70	70	70

Flaps were also assessed at 0 hr, 1 hr, 3 hr, 6 hr, 12 hr, 24 hr, and 48 hr using the FLIR camera.

- At O and 1 hour, all the flaps were normal on FLIR pictogram.
- At 3 hours, blue spots seen in 2 patients and white in 1 patient.
- At 6 hours, blue spots seen in 2 patients, white in 1 patient and white with yellow spots in 1 patient.
- At 12 hours, blue spots seen in 1 patient and white spots in 4 patients.
- At 24 hours, blue spots seen in 2 patients and white spots in 5 patients.
- At 48 hrs , 62 flaps had normal imaging, blue spots seen in 4 patients and white spots in 4 patients.

Figure 8: Frequency distribution of total cases (n=70) according to findings on FLIR pictogram of flaps in post operative period

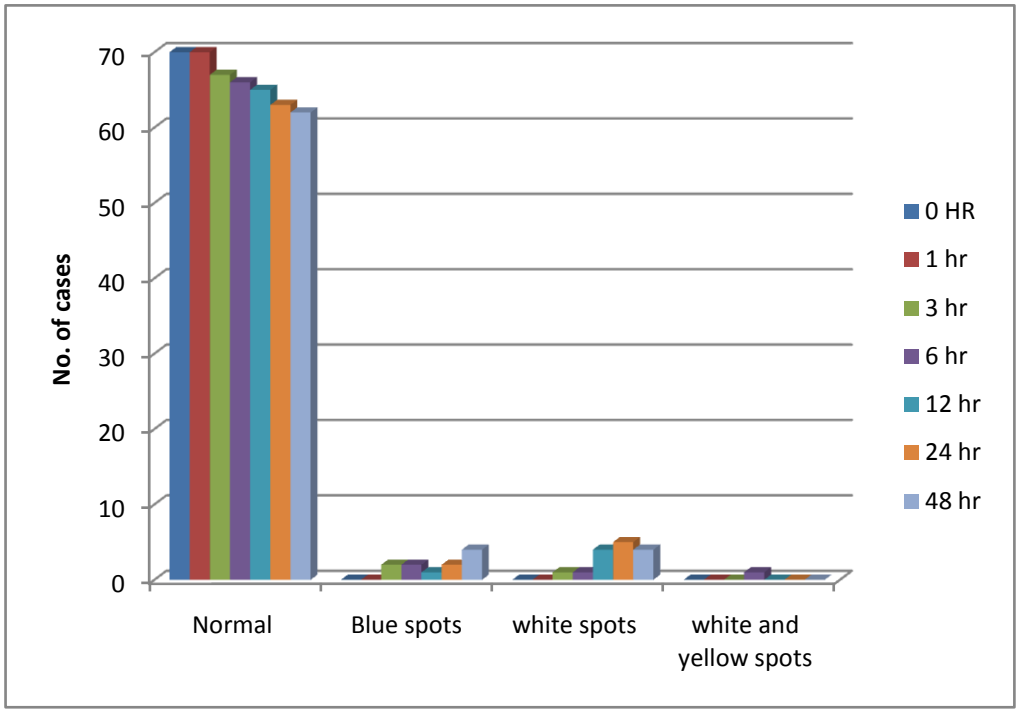


TABLE 9: Frequency distribution of total cases (n=70) according to final outcome of flaps

Final outcome		No of cases	%
Complication	NO	63	90.0%
	YES	7	10.0%
Venous insufficiency	NO	66	94.3%
	YES	4	5.7%
Arterial insufficiency	NO	67	95.7%
	YES	3	4.3%
Necrosis	NO	65	92.9%
	YES	5	7.1%
Survival	NO	5	7.1%
	YES	65	92.9%

Table 9 shows, final outcome at end of 48 hours, out of 70 flaps, 63 flaps remained healthy whereas 7 flaps developed complications (both on clinical and FLIR observation)

Of these 7 flaps, venous insufficiency was seen in 4 flaps and arterial insufficiency in 3 flaps.

Out of 7 flaps, 5 flaps developed necrosis and 2 flaps could be salvaged with timely intervention.

Figure 9: Frequency distribution of total cases (n=70) according to final outcome of flaps

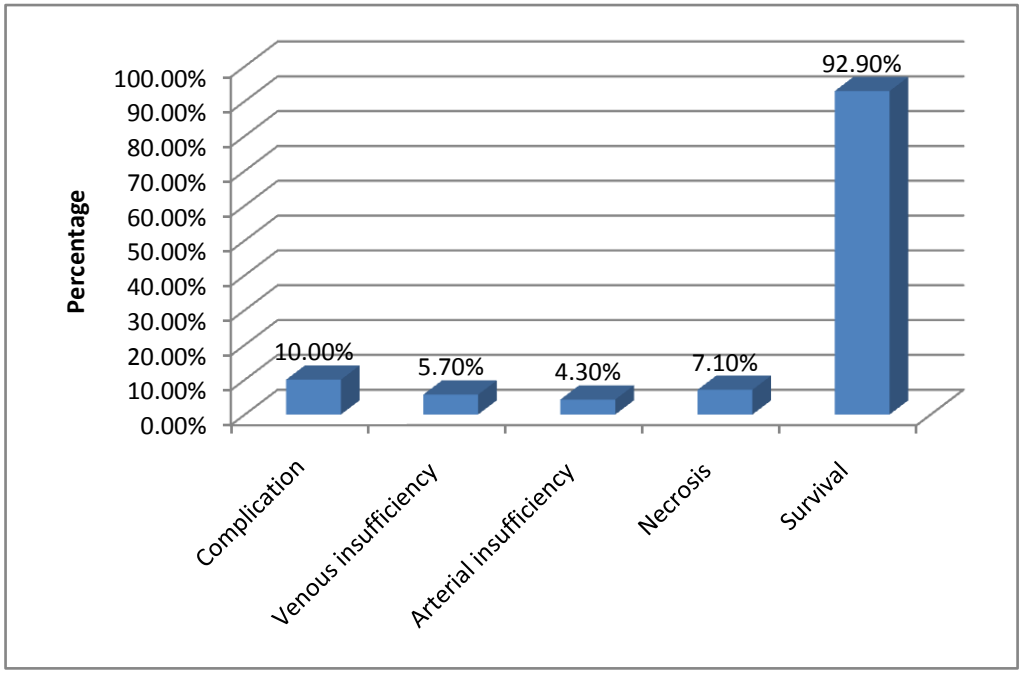


TABLE 10: Detailed description of complicated cases (n=7) according to findings on clinical examination and FLIR pictogram

CAUSE	AGE	FLAP	SITE	CLINICAL DETECTION	FLIR DETECTION	INSUFFICIENCY	OUTCOME
MALIGNANCY	48Y	PMMC	ORAL CAVITY	12 hrs	3 hrs	Arterial	Survived
TRAUMA	35 Y	FREE LD FLAP	FOOT	6 hrs	3 hrs	Venous	Failed
TRAUMA	25Y	FREE ALT FLAP	SCALP	6 hrs	3 hrs	Arterial	Failed
MALIGNANCY	38Y	FREE ALT FLAP	HAND	1 HR	12 hrs	Venous	Failed
TRAUMA	19 Y	REVERSE SURAL ARTERY FLAP	FOOT	12 hrs	No change	Venous	Survived
TRAUMA	42Y	TRANSPOSITION FLAP	LEG	12 hrs	48 hrs	Venous	Failed
TRAUMA	47Y	REVERSE SURAL ARTERY FLAP	HEEL	12 hrs	No change	Arterial	Failed

Case 1: 48-Year-Old Male – Pectoralis Major Myocutaneous Flap

Diagnosis: CA Right Buccal Mucosa + Floor of Mouth

Evaluation: The flap remained normal (N) till 12 hrs with arterial bleeding on clinical examination. However, by 3 hours, blue spots were detected, indicating potential areas of compromised perfusion on FLIR pictogram. These spots persisted through the 6- and 12-hour marks.

Comparison: **Flir camera detected abnormal response earlier** than monitoring by clinical assessment

Complication: The suture was removed, and a heparin spray was applied to address delayed arterial flow.

Outcome: The flap survived as confirmed on clinical examination after 5 days.

Case 2: 35-Year-Old Male – Free Latissimus Dorsi Flap

Diagnosis: Post Trauma Foot Defect

Evaluation: The flap showed normal arterial perfusion initially. At 3 hours FLIR pictogram whitish spots were noticed.

By 6 hours, on clinical evaluation the flap started showing signs of venous insufficiency like venous bleed and bluish discolouration.

Comparison: **Flir camera detected abnormal response earlier** than monitoring by clinical assessment

Intervention: Suture removal was done at 8 hrs

Outcome: Significant venous issues were identified, leading to flap failure.

Case 3: 25-Year-Old Male – Free ALT Flap (Scalp)

Diagnosis: Post Machine Injury Scalp Defect

Evaluation: Normal initial readings, but at 6 hours, the flap had delayed arterial bleed , followed by absent prick at 8 hrs.

Flir pictogram revealed development of blue spots at 3 hours postoperatively indicating areas of hypoperfusion. .

Comparison: **Flir camera detected abnormal response earlier than monitoring** by clinical assessment

Intervention: Arterial thrombectomy was performed 8 hours post-surgery due to a

Outcome: Flap did not survive despite operative intervention.

Case 4: 38-Year-Old Male – Free ALT Flap (Hand)

Diagnosis: Post Sarcoma Left Hand Defect

Evaluation: The flap was normal initially but showed venous insufficiency by the 1hour mark with mixed pin prick which then was venous starting from 3 hours.

FLIR pictogram picked up white spots at 12 hours.

Comparison: Flir camera detected vascular insufficiency later than monitoring by clinical assessment

Intervention: Heparin spray was applied, and skin scratching was performed starting at 10 hours post operative.

Outcome: Venous issues persisted, flap did not survive.

Case 5: 19-Year-Old Male – Reverse Sural Artery Flap (Foot)

Diagnosis: Post Trauma Heel Defect

Evaluation: The flap demonstrated venous bleeding on pin prick at 12 and 24 hours with other clinical parameter being normal and the FLIR camera did not identify any significant issues.

comparison: clinical assessment was able to detect abnormal response better than FLIR camera

Intervention: Suture removal with heparin spray was required.

Outcome: Despite some minor venous insufficiency, the flap remained viable.

Case 6: 42-Year-Old Male – Transposition Flap (Leg)

Diagnosis: Post Trauma Leg Defect

Evaluation: Initial readings were normal, but signs of venous insufficiency including color change and venous pin prick appeared by 12 hours.

Flir camera picked up changes at 48 hours only.

Intervention: Heparin spray was used, and sutures were removed 12 hours post-surgery.

Outcome: The flap exhibited significant venous problems, and couldn't be salvaged.

Case 7: 47 year old Male – Heel defect

Diagnosis: Post trauma heel defect

Evaluation: On clinical evaluation, by 12 hours, the flap showed signs of arterial insufficiency with delayed pin prick followed by absent arterial bleed.

FLIR camera did not show any signs of vascular compromise.

Intervention: The patient received Clexane injections and had sutures removed.

Outcome: Flap did not survive.

TABLE 11: Comparison of FLIR finding with clinically complicated cases at various time intervals

		CLINICALLY COMPLICATIONS AT 48 HRS				Total	Chi-square value	p-value
		NO		YES				
FLIR CAMERA PICTOGRAM_0HR	N	63	100.0%	7	100.0%	70		
1HR	N	63	100.0%	7	100.0%	70		
3 HR	BLUE SPOTS	0	0.0%	2	28.6%	2	28.209	0.001
	WHITE	0	0.0%	1	14.3%	1		
	N	63	100.0%	4	57.1%	67		
6 HR	BLUE SPOTS	0	0.0%	2	28.6%	2	28.249	0.001
	WHITE	1	1.6%	0	0.0%	1		
	WHITE AND YELLOW	0	0.0%	1	14.3%	1		

	N	62	98.4%	4	57.1%	66		
12 HR	BLUE SPOTS	0	0.0%	1	14.3%	1	17.179	0.001
	WHITE	2	3.2%	2	28.6%	4		
	N	61	96.8%	4	57.1%	65		
24 HR	BLUE	1	1.6%	1	14.3%	2	9.489	0.009
	WHITE	3	4.8%	2	28.6%	5		
	N	59	93.7%	4	57.1%	63		
48 HR	BLUE	1	1.6%	3	42.9%	4	21.613	0.001
	WHITE	3	4.8%	1	14.3%	4		
	N	59	93.7%	3	42.9%	62		
Total		63	100.0%	7	100.0%	70		

Table 11 shows comparison of FLIR camera pictogram findings with clinical observations at various time intervals.

At end of 48 hours, clinically 7 patients developed complications.

- All flaps were normal on FLIR pictogram at 0 and 1 hours.
- At 3 hours, out of 7 clinically complicated cases, FLIR showed blue spots in 2 patients and white spots in 1 patient which is statistically significant with a p value of 0.001.
- At 6 hours, out of 7 clinically complicated cases, FLIR showed blue spots in 2 patients and white and yellow spots in 1 patient which is statistically significant with a p value of 0.001.
- At 12 hours, out of 7 clinically complicated cases, FLIR showed blue spots in 1 patient and white spots in 2 patients which is statistically significant with a p value of 0.001.
- At 24 hours, out of 7 clinically complicated cases, FLIR showed blue spots in 1 patient and white spots in 2 patients which is statistically significant with a p value of 0.009.
- At 48 hours, out of 7 clinically complicated cases, FLIR showed blue spots in 3 patients and white spots in 1 patient which is statistically significant with a p value of 0.001.
- Also 4 flaps out of 63 clinically non complicated ones, FLIR pictogram showed blue spots in one patient at 24 hrs and one patient at 48 hours and white spots in one patient at 6 hours, 2 at 12 hours and 3 at 24 and 48 hours (false positive results) These patients had no features of flap compromise till discharge.

Figure 10: Comparison of FLIR finding with clinically complicated cases at various time intervals

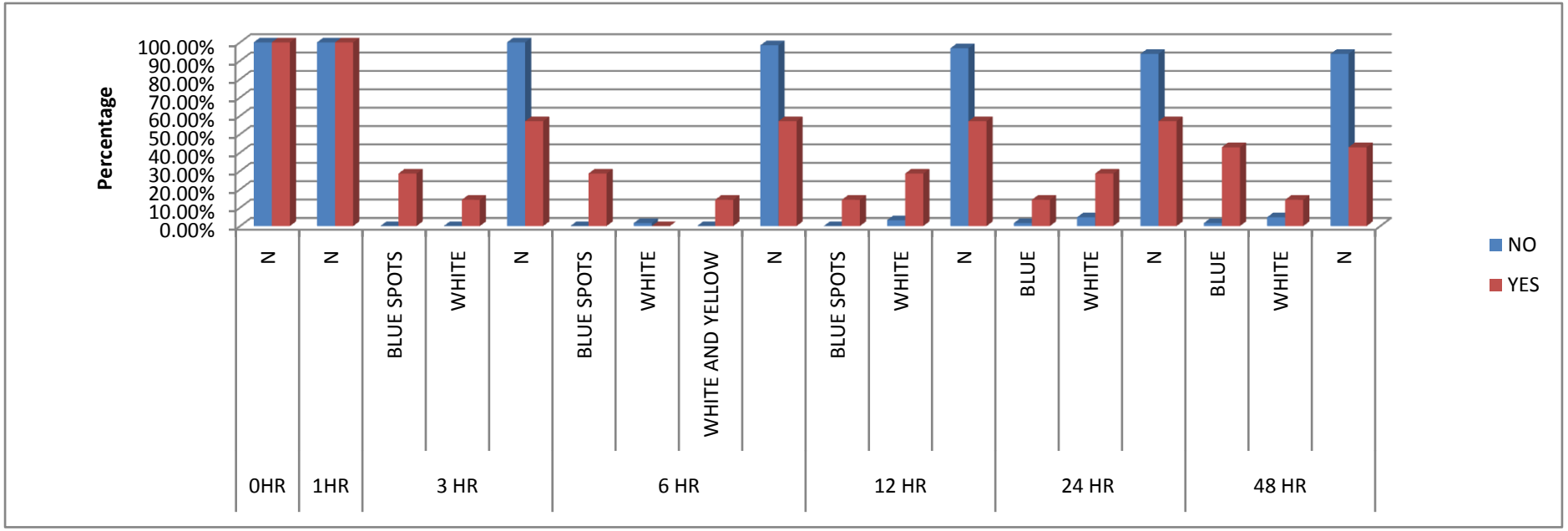


TABLE 12: Statistical analysis of FLIR pictogram in total (n=70) cases.

		COMPLICATION				Total	kappa value	p-value
		NO		YES				
FLIR CAMERA PICTOGRAM	YES	4	1.6%	5	42.9%	9	0.577	0.001
	N	59	93.7%	2	42.9%	61		
Total		63	100.0%	7	100.0%	70		

Table 12 shows, out of 63 flaps with no complications, FLIR pictogram showed abnormal spots in 4 flaps (false positive results)

Out of 7 flaps with complications, FLIR camera was able to detect changes in 5 flaps, with earlier detection than clinical examination in 3 flaps which is statistically significant with p value of 0.001.

Figure 11: **Statistical analysis of FLIR pictogram in total (n=70) cases.**

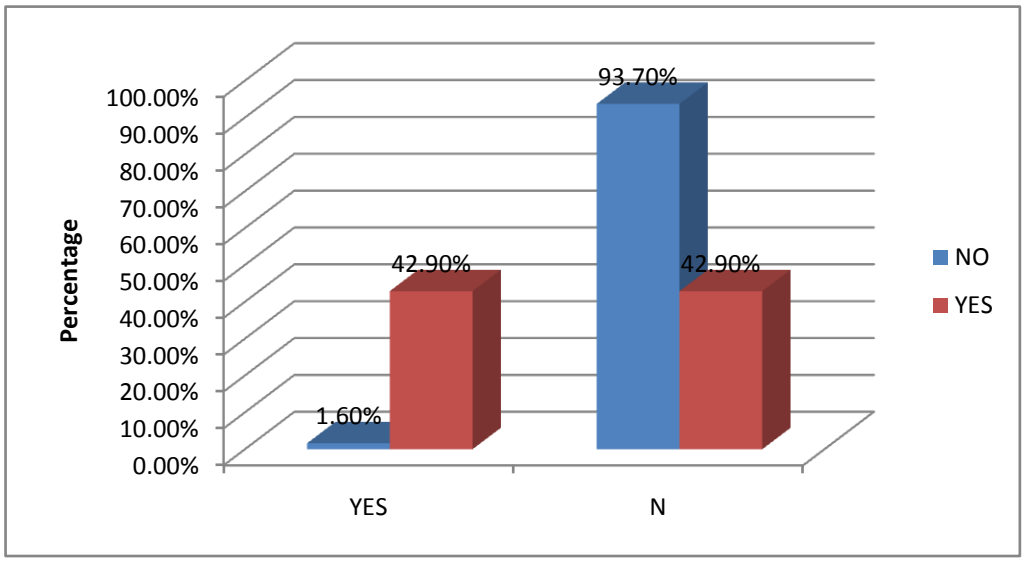


TABLE 13: Frequency distribution of total cases (n=70) according to intervention required in post operative period

INTERVENTION REQUIRED	No. of cases	Percentage
NO	63	90.0%
SCRATCH SKIN PADDLE AND HEPARIN SPRAY	1	1.4%
SUTURE REMOVAL	1	1.4%
SUTURE REMOVAL WITH HEPARIN SPRAY	3	4.3%
SUTURE REMOVAL AND INJECTION LMWH SUBCUTANEOUSLY	1	1.4%
EXPLORATION AT 8 HRS WITH ARTERIAL THROMBECTOMY	1	1.4%
Total	70	100.0%

Table 13 shows of the 70 flaps, in 7 flaps an intervention was done for salvage.

The most common intervention performed was suture removal with heparin spray in 3 cases.

Figure 12: Frequency distribution of total cases (n=70) according to intervention required in post operative period

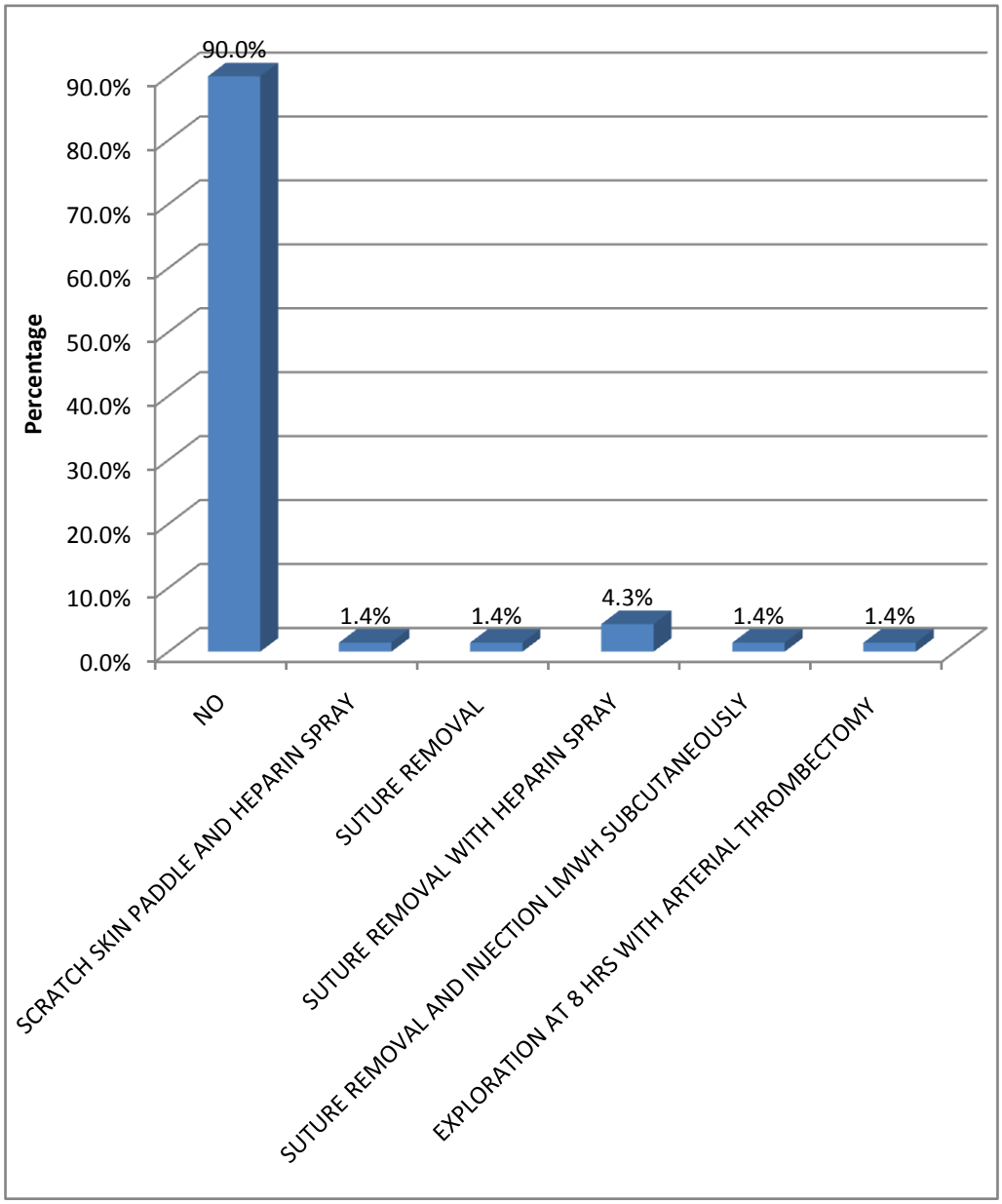
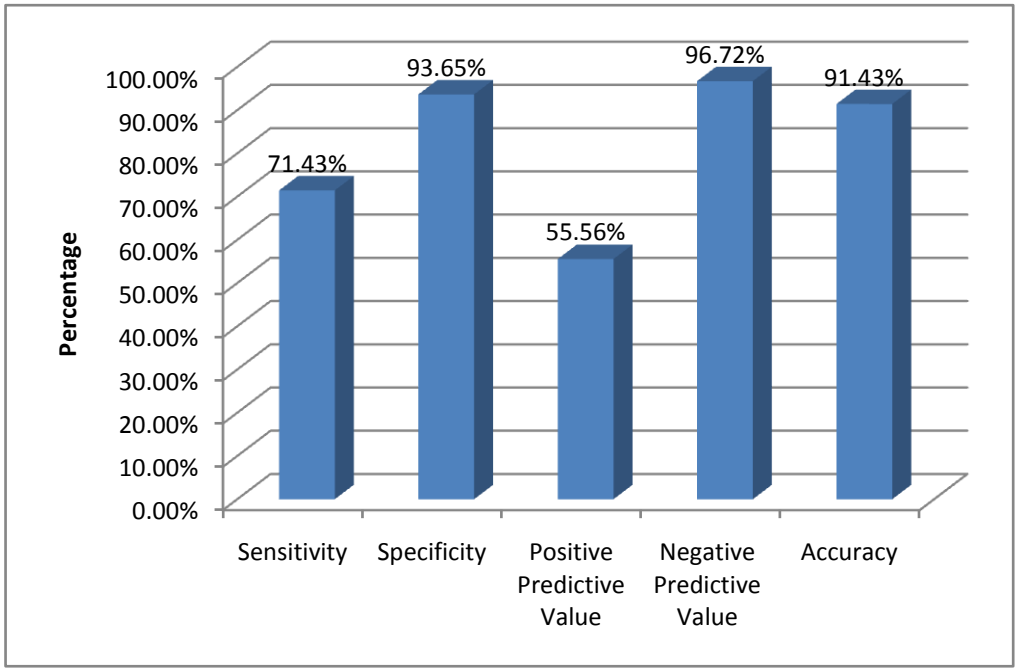


TABLE 14: Statistical analysis of role of FLIR camera in post operative flap monitoring

Statistic	Value	95% CI
Sensitivity	71.43%	29.04% to 96.33%
Specificity	93.65%	84.53% to 98.24%
Positive Likelihood Ratio	11.25	3.91 to 32.40
Negative Likelihood Ratio	0.31	0.09 to 0.99
Disease prevalence (*)	10.00%	4.12% to 19.52%
Positive Predictive Value (*)	55.56%	30.27% to 78.26%
Negative Predictive Value (*)	96.72%	90.13% to 98.96%
Accuracy (*)	91.43%	82.27% to 96.79%

Table 14 shows that FLIR camera has sensitivity of 71.43% and specificity of 93.65% with diagnostic accuracy of 91.43%.

Figure 13: Statistical analysis of role of FLIR camera in post operative flap monitoring



DISCUSSION

Since the advent of plastic and reconstructive surgery, transfer of a unit of tissue along with its blood supply, known as flap [19] has a significant role in coverage of complex defects. These flaps can be pedicled or free.

Pedicled flaps retain their original blood supply, offering robust vascularity and reliability [19]. Free flaps involve microsurgical reconnection of blood vessels at the recipient site, allowing for complex reconstructions [22]. The final outcome of any flap (free or pedicled) depends greatly on postoperative monitoring for early detection of any vascular compromise warranting intervention for salvage [23]. Worldwide, the failure rate of pedicled flaps ranges from 1 to 10% [21,65] and that of free flaps ranges from 1 to 6% [22,64].

Vascular compromise usually occurs within first 72 hours of flap surgery [21]. Therefore, early detection of any decrease in vascularity followed by early intervention before the permanent injury to the flap, maximises the chances of flap salvage [21,22,23]

So, the method used for post operative flap monitoring should be quick, accurate, reliable and easy to execute.

Till date, clinical assessment is considered the gold standard method for postoperative flap monitoring, but it is subjective and depends on the observer's experience [26]. It involves observing skin color, turgor, temperature, and capillary refill time [27]. Specific signs indicate whether blood flow issues are due to arterial insufficiency or venous congestion. Features such as cyanosis and discoloration with venous pinprick indicate venous insufficiency, while features like pale color, cold temperature, and prolonged capillary refill time indicate arterial insufficiency [26]. Because this method is subjective, the chances of errors are always there [26].

Besides these subjective methods, various objective devices are used for flap monitoring, as reported in the literature. Few of them are listed in Table 15 [26].

Table 15: Summary of Invasive and Non-Invasive Free Flap Monitoring Techniques

Non-invasive	Invasive
Clinical assessment (gold standard)	Implantable Doppler/venous coupler [28,29]
Color duplex sonography [27]	Microdialysis [30,40]
Acoustic cutaneous Doppler	Tissue ph monitoring [31]
Laser Doppler flowmetry	Oxygen tension monitoring
Microlight-guided spectrophotometry	Technetium-99m sestamibiscintigraphy [30]
Surface temperature monitoring [32]	Contrast-enhanced Doppler [29]
Tissue oximetry	Biochemical markers from free-flap blood
Fluorescence imaging [25,31]	Perfusion-weighted MRI [30,31]

Color duplex ultrasonography is a non-invasive method of postoperative flap monitoring by visualizing flow through the vessels using a handheld probe and viewing monitor. This method requires high-cost equipment and expertise [27].

Implantable Doppler, also called Cook–Swartz Doppler, consists of a silicon cuff mounted with a piezoelectric crystal, which is wrapped around the blood vessel (artery, vein, or both) and connected externally to a cutaneous acoustic Doppler. It has been used for flap monitoring since 1988[28,29]. Though reported to be very accurate, major disadvantages include the device's cost and potential for failure, leading to unnecessary reoperation [28].

Microdialysis is a sampling technique used to continuously monitor glucose, lactate, and lactate/pyruvate ratios in the flap with a bedside analyzer . This method is accurate and continuous but invasive, with limited literature available on its effectiveness [40].

However, no universally established gold standard exists among these modalities. Each method has limitations, such as the need for specialized equipment, potential invasiveness, and operator dependency [30,31].

The recent advancements in smartphone technologies marks the start of breakthrough era for promising techniques of monitoring flaps [25].

Thermal imaging camera has recently been introduced in medical science which converts infrared electromagnetic radiations to a pictorial format that are proportional to the temperature which indicates vascularity at various points in a flap and where different colours are specific for a temperature gradient. Overall, brighter images are produced with a default colour range from dark blue that represents the coolest body part to garish yellow or white that represent the hottest part. Different shades of red and orange show body parts with intermediate temperature levels[7]

A thermographic camera (also known as infrared camera or thermal imaging camera) uses infrared radiation to form an image. The operating wavelength of the thermal camera is 14,00 nm,17 which differs it from an ordinary light digital camera (wavelength of 400–700 nm [33] FLIR ONE® is a low cost imaging device that couples with micro-USB port of Android or lightening port of ios smartphones. It uses a second light camera to capture still or moving real time image for comparison. Furthermore, absolute temperature estimation is also possible for a specific spot.[7] Thereby making it an excellent tool to access the underlying perforator(if any) in flaps.

This study was conducted on 70 patients over 19 months in Department of Plastic and Reconstructive Surgery at DMCH, Ludhiana assessing the role of thermal imaging in post operative flap monitoring of patients who underwent flap surgeries.

The mean age in this study was 32.67, and 92.9% were male, similar to study conducted by Rabbani et al with mean age of patients being 29.21±11.744 years and males (70, 83.3%) outnumbering females (14, 16.7%) [7]. Trauma was the most common etiology for defect, accounting for 45.71% cases followed by

malignancy (31.42%) and burns (17.14%), while infection and pressure injury contributed to a relatively small percentage (2.8% each). This data aligns with Mohan et al. [34] and Nguyen et al. [59] in which the most common cause of patients undergoing flap surgery was trauma. The significant prevalence of trauma aligns with global trends, where traumatic injuries are a leading cause of flap surgeries and reconstructions. Patel et al. [56] and Meyer et al. [46] observed in their studiesthat malignancies are more common causes requiring surgical flaps, particularly in the context of reconstructive surgery.

In this study, The most common site of flap transfer was head and neck region similar to study conducted by Patel et al. [56] shows head and neck as most common site.

The most common type of flap performed in this study was groin flap, as also reported by Mohan et al.[34] . He highlighted the cases where the groin area provided sufficient tissue for transfer in reconstructive procedures, emphasizing the groin flap's versatility and utility in surgical contexts. Whereas most common flap in study conducted by Meyer et al [46] is free fibula flap and anterolateral thigh flap in study by P Singla [39]

The flaps were monitored postoperatively using clinical assessment and thermal imaging via the FLIR camera at 0, 3, 6, 12, 24, and 48 hours . Clinical parameters such as flap color, temperature, type of bleed on a prick, and capillary refill were evaluated. The FLIR camera produced a pictogram, recording specific spots [32,7].

Monitoring the color of the flap postoperatively is crucial for assessing its viability, as changes in color often serve as early indicators of vascular compromise. Across multiple studies, skin discoloration has been a key marker for detecting issues such as congestion, ischaemia or necrosis. Patel et al. [56] and Nguyen et al. [59] highlighted that cyanosis (bluish discoloration) typically appears within the first few hours when venous congestion is present, and if left unchecked, this can progress to necrosis. In our study also initially, all patients had normal skin color, but few cases began to exhibit discoloration at 6 hours. The bluish discoloration was seen in

one patient at 6 hours and in 2 patients at 48 hours. Blackening of margins were observed in one patient each at 12 hours and 48 hours. One flap was pale at 48 hours.

Luze et al. (2022) reported that capillary refill time is a reliable marker of perfusion, with prolonged refill time indicating venous obstruction [33]. In present study, most patients had normal capillary refill times, though delayed refill was observed in two patients by 6 hours, increasing to four patients by 48 hours.

Flap monitoring is focussed on detecting the early signs of vascular compromise which include monitoring for changes in blood flow and perfusion that would correlate with clinical signs like arterial or venous bleeding [7]. At 48 hours, four patients exhibited dark-colored blood on pinprick, indicating venous insufficiency, while two patients had absent bleeding, indicating arterial insufficiency [7]. Similar findings were seen in study conducted by P Singla [39] with dark coloured bleed showing venous insufficiency in 3 patients and absent prick in 2 patients indicating arterial insufficiency.Patel et al. Combined clinical temperature monitoring with thermal imaging, showing that thermal imaging provided more detailed, real-time assessments of perfusion [56].

In this study, temperature monitoring remained normal for most patients until 3 hours postoperatively. By 6 and 12 hours, temperature had increased in one patient. At 24 hours, 66 patients had normal temperatures, with increases in one patient and decreases in three patients [7]. Similar findings were reported by Rabbani et al. [7],Khouri et al [35], Meyer et al [46] and observed that temperature decreases significantly in failing flaps.

Thermal imaging using the FLIR camera provides a non-invasive method for monitoring tissue perfusion, detecting heat patterns that indicate compromised blood flow [32,7]. Coninckx et al. Demonstrated that the FLIR ONE device effectively detects temperature changes related to perfusion failure [32]. Gray et al. Reviewed the FLIR ONE's practical applications in postoperative flap monitoring, emphasizing its real-time capabilities [44].

In this study, the pictogram obtained at the 3-hour showed two patients with blue spots (indicating cold areas with potential perfusion compromise), and one patient showed white (indicating poor blood flow). The majority of patients (95.7%) had normal pictogram. At 6 hours postoperatively, the number of patients showing blue spots remained the same. However, one patient presented with both white and yellow colors, possibly indicating cold ischemia and risk of necrosis. At 12 hours,4 patients show white color and at 24-hour , 2 patients show blue spots, and 5 patients show white (likely ischemia),. By 48 hours, 4 patients show blue spots and another 4 continue to show white color.

These results align with various studies that detected vascular compromise as early as 6 hours postoperatively. The following table **TABLE 16: Gives the various studies that employed thermal imaging to detect vascular compromise and the earliest time they were able to detect it:**

Study	**Detection Time (Post-Surgery)**
Luze et al.[33] (2022)	Intraoperative/first few hours
Mohan et al.[34] (2024)	6 hours
Frohwitter et al.[38] (2021)	6 hours
Nelson et al. [41] (2021)	6 hours
Patel et al. [56] (2020)	6-8 hours
Hallock [48] (2019)	8 hours
Rabbani et al. [7] (2021)	6-12 hours
Çetinkaya et al. [37] (2024)	6-12 hours

In present study of 70 patients, 63 had successful flap, while seven patients developing complications. Of these seven patients, five had flap failure. The success rate of flap surgeries in this study is 92%, which is comparable to other studies, such as 80% (Mohan et al. 2024) and 92-94% (Patel et al.) [34,56].

Of the 63 patients who had successful flap survival, clinical parameters were normal in all cases, but FLIR pictograms (false positives) displayed the appearance of blue spots in one patient and white spots in three patients. Of the four cases with ambiguous findings, two patients had groin flaps and two had pectoralis major myocutaneous flaps. In one patient, the white spots developed as early as 6 hours and persisted until 48 hours. In the other patients, the spots were noted at the 12- and 24-hour, respectively. No interventions were done in these cases as the clinical parameters were within normal range throughout, as highlighted in materials and methods. These patients were subjected to rigorous monitoring after positive FLIR findings. As a protocol, intervention was done only if there is a clinical indication of vascular compromise as this FLIR thermal imaging camera is still in its research phase.

The ambiguity in the findings can be explained by the observations made by Romero et al [63] where they cited that various factors could contribute to debatable thermal imaging results. These factors include the influence of ambient temperature, variations in skin temperature, and the limitations of lower-resolution devices, such as those used in smartphone thermal imaging. Furthermore, external thermal interference and challenges in interpreting the color scales used in thermal imaging can also lead to unclear or misleading outcomes. [63]

Of the seven patients who developed complications in this study, the FLIR pictogram was able to detect vascular compromise in five patients. In three patients, thermal imaging detected vascular compromise as early as 3 hours, while clinical parameters began to display compromise after 6-12 hours. However, in two cases, the FLIR pictogram detected vascular compromise after clinical signs had already appeared, and in two other cases, the FLIR camera failed to detect the compromise (false negatives).

In this study, we found that 57.1% of patients with venous insufficiency experienced complications, and 42.9% of those with arterial insufficiency had failed outcomes. These findings align with research conducted by Mohan and Rabbani, reaffirming the crucial role of early

detection and prompt management of vascular complications in improving the success rate of flap surgeries [34,7]. Of these seven patients, two patients each with venous and arterial insufficiency were salvaged.

In this present study, the diagnostic accuracy of FLIR thermal imaging camera came out to be 91.43%. The specificity of FLIR camera being 93.65% indicates that FLIR camera can be very useful tool for flap monitoring.

The kappa value of 0.577 suggests moderate agreement between the FLIR camera results and actual outcomes, and a p-value of 0.001 indicates that the results are statistically significant.

Although the results are acceptable and statistically significant, they differ from other studies, like Rabbani et al [7], P Singla et al. [39] which show higher sensitivity value by FLIR camera than this present study, as shown in table 17.

The reasons for these differences could be external factors like patient movement, ambient temperature, different thermal palettes of cameras, and the use of smartphones versus professional-grade cameras, as noted by Patel et al.[56] (2020) and Frohwitter et al. (2021) [38].

TABLE 17: Comparative analysis of sensistivity and specificity of thermal imaging camera in various studies

Study	Sensitivity	Specificity
This study	71.43%	93.65%
Rabbani[7]	98.7%	75%
Singla[39]	88.6%	98.9%
Cruz [58]	90%	85%
Khouri [35]	98%	75%

Just et al. described various internal factors, such as body temperature, respiratory flow, and local inflammatory reactions, and external factors like room temperature, air humidity, or the camera's axis relative to the patient's position, which could affect surface temperature readings of the flap [66].

Studies like Nelson et al. (2021) have highlighted the challenge of using thermal imaging on patients with darker skin tones, as melanin absorbs heat differently, which can affect the precision of thermal readings [41]. Also, the performance of thermal imaging can vary depending on the device used. For instance, low-cost, smartphone-based thermal cameras may not offer the same resolution and accuracy as high-end infrared systems, as noted by Mohan et al. (2024) and Rabbani et al. (2021) [34,7]. Hence, all the above factors had to be meticulously dealt with during temperature monitoring.

Inspite of having a lower sensitivity, this present study demonstrates high specificity and diagnostic accuracy. This method is undoubtedly an easy, objective, fast and lesser user dependant for flap monitoring. With fast growing artificial intelligence advancements, this objective tool has the potential to be an excellent adjunct along with clinical monitoring, similar suggestions has been made by Luze et al. He suggested that thermal imaging should ideally be used in conjunction with other monitoring techniques, such as Doppler or indocyanine green angiography, to improve diagnostic accuracy .These limitations underscore the need for a multimodal approach to flap monitoring, combining thermal imaging with other methods to ensure comprehensive assessment and timely interventions [33].

This combining thermal imaging with other methods will prove to be an excellent asset for flap monitoring in this era of advance technologies. To conclude, thermal imaging has emerged as a promising, non-invasive tool for the early detection and management of vascular compromise in flap surgeries. Across multiple studies, its utility in detecting subtle temperature changes indicative of venous or arterial insufficiencies has been well documented [7,32,62]. Despite its benefits, thermal imaging does exhibit limitations, as mentioned above. Studies demonstrate that when thermal imaging is combined with other techniques, such as doppler ultrasound or indocyanine green angiography, it can significantly enhance the accuracy of flap viability assessments, reducing the risk of complications and improving patient outcomes [33,34]. Ultimately, the integration of thermal imaging into the

multimodal diagnostic framework including clinical observation represents a valuable advancement in the field of reconstructive surgery, enabling timely interventions that preserve tissue integrity and improve surgical success rates. However, ongoing refinement in technology and its application across diverse patient populations remains essential to fully realize its potential.

SUMMARY AND CONCLUSION

A prospective study of role of thermal imaging smartphone camera in post operative flap monitoring was done in the department of plastic and reconstructive surgery at Dayanand Medical College and Hospital, Ludhiana from October 2022 to February 2024(19 months). This study included 70 patients who had undergone any type of flap surgery. Flap monitoring with clinical assessment and FLIR pictogram was done at 0,1,3,6,12, 24 and 48 hours. In clinical evaluation, flap color, capillary refill, temperature and bleeding characteristics were observed.

Summary of observations include:

▪In this study, the mean age of patients was 32.67, and 92.9% were male.

▪Trauma was the most common etiology for defect, accounting for 45.71% cases followed by malignancy (31.42%) and burns (17.14%), while infection and pressure injury contributed to a relatively small percentage (2.8% each).

- ▪ The most common site of flap transfer was head and neck
- ▪ The most common type of flap performed in this study was groin flap, followed by radial artery free forearm flap.
- ▪ Out of 70 flaps, 63 flaps survived with success rate of 92%.
- ▪ Out of 7 complicated flaps, 5 developed flap failure.
- ▪ The diagnostic accuracy of FLIR camera came out to be 91.43%, with specificity of 93.65%
- ▪ The sensitivity of FLIR camera was 71.43 %

Therefore, our results suggest that inspite of having a lower sensitivity, FLIR thermal imaging camera has high specificity and diagnostic accuracy.

To conclude, thermal imaging has emerged as a useful tool for the early detection and management of vascular compromise in flap surgeries. FLIR camera is objective, fast and lesser user dependant for flap monitoring. Across multiple studies, its utility in detecting subtle temperature changes indicative of venous or arterial insufficiencies has been well documented. Also being an objective method, pictograms

can be obtained by nursing staff and doubtful images can be further analysed by operating team and can be confirmed on clinical assessment.

Objective information can be added to subjective clinical findings and thus improving the chances of flap survival. Clinical assessment is dependent on observers experience, therefore integration of objective assessment using thermal camera decreases the chances of error . This multimodal approach will enable us to detect compromised flap perfusion and do timely interventions and hereby improve the surgical success rate.

Despite its benefits, thermal imaging does exhibit limitations, as mentioned in discussion .Various studies in literature demonstrates that incorporation of thermal imaging along with clinical monitoring with other methods of flap monitoring like duplex ultrasonography further enhances the accuracy of flap viability assessment. FLIR camera is still in its research phase and needs further studies with large sample size to fully explore its potential.

We hereby conclude that FLIR thermal imaging camera is a useful tool as an adjunct to clinical assessment for post operative flap monitoring.

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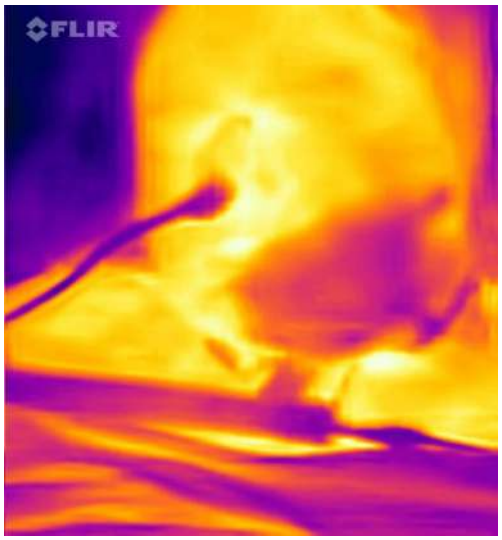
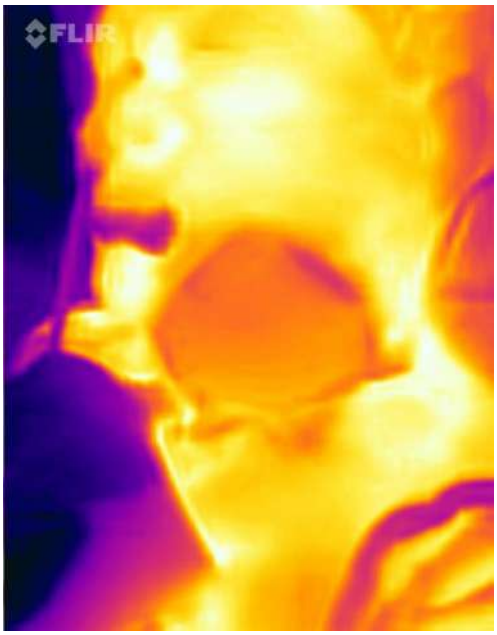
PICTURE 1: PECTORALIS MAJOR MYOCUTANEOUS FLAP FOR HEAD AND NECK MALIGNANCY CLINICAL PICTURE IN EARLY POST OPERATIVE PERIOD



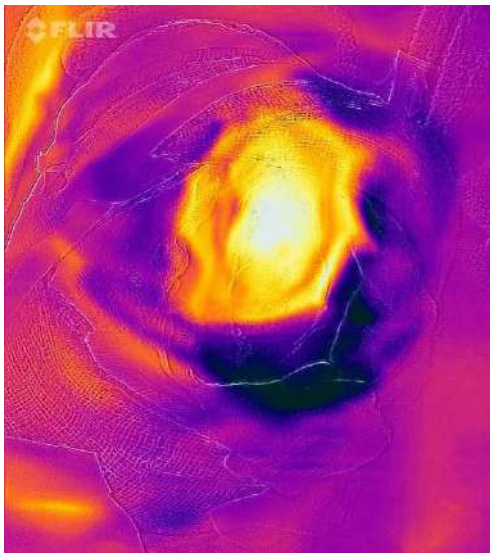
PICTURE 2: FLIR PICTOGRAM SHOWING BLUE SPOTS, INDICATING VASCULAR COMPROMISE

PICTURE 3: IMPROVED VASCULARITY ON CLINICAL EXAMINATION OF FLAP AFTER SUTURE REMOVAL



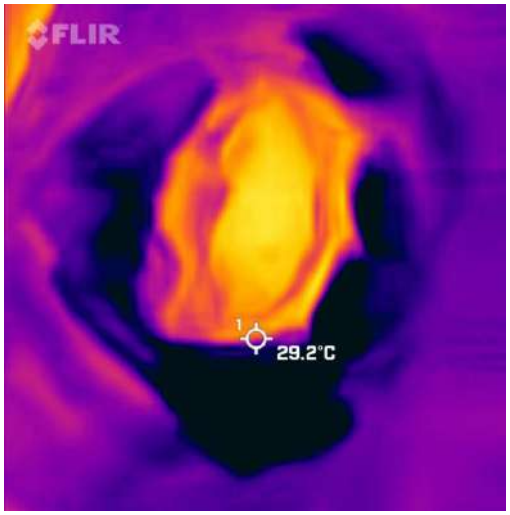
PICTURE 4: IMPROVED VASCULARITY OF FLAP ON FLIR PICTOGRAM WITH DECREASE IN BLUE SPOTS AFTER SUTURE REMOVAL

PICTURE 5: POST TRAUMA FREE LD FLAP, CLINICAL PICTURE IN EARLY HOURS



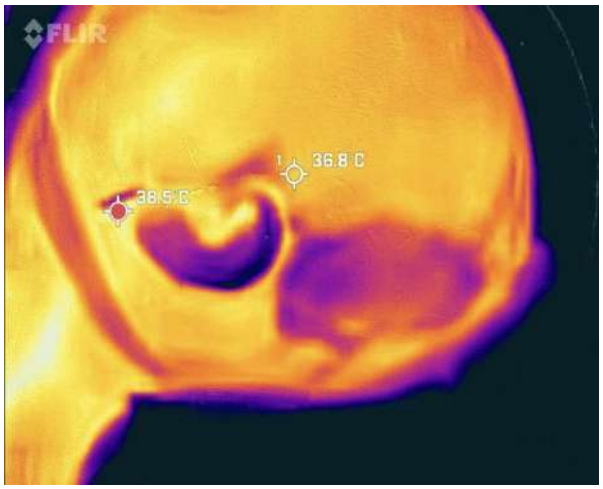
PICTURE 6: FLIR PICTOGRM AT 3 HRS SHOWING WHITE SPOTS INDICATIVE OF RAISED TEMPERATURE DUE TO POTENTIAL VENOUS INSUFFICENCY

PICTURE 7: CLINIVAL PICTURE OF FREE LD FLAP AT 6 HRS SHOWING VENOUS BLEED ON PIN PRICK, INDICATING VENOUS INSUFFICIENCY



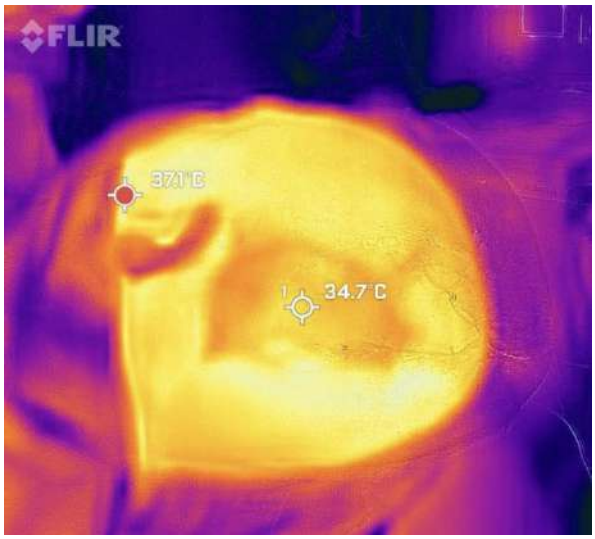
PICTURE 8: FLIR PICTOGRAM SHOWING ADDITION OF BLUE SPOTS INDICATING VASCULAR COMPROMISE

PICTURE 9: POST TRAUMA SCALP DEFECT COVERAGE WITH FREE ALT FLAP SHOWING ABSENT PIN PRICK ON CLINICAL EXAMINATION



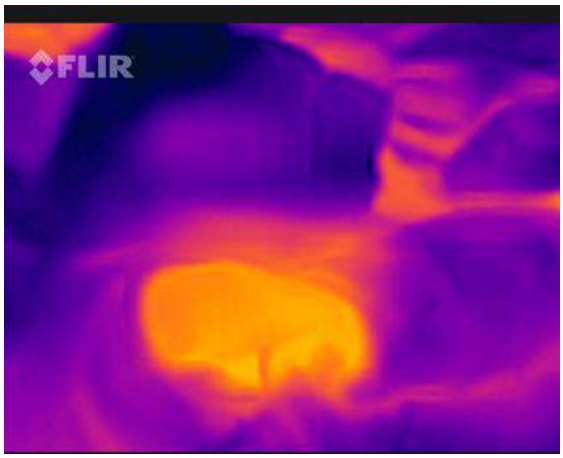
PICTURE 10: FLIR PICTOGRAM SHOWING BLUE SPOTS INDICATING VASCULAR COMPROMISE

PICTURE 11: SHOWS ARTERIAL PIN PRICK IN FLAP AFTER SURGICAL INTERVENTION (ARTERIAL THROMBECTOMY)



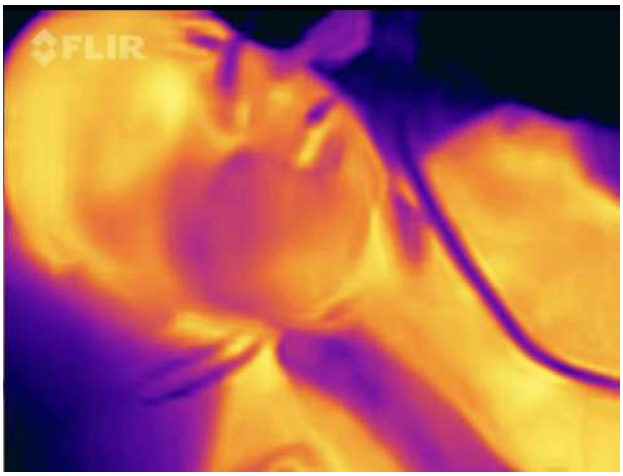
PICTURE 12: FLIR PICTOGRAM SHOWING IMPROVED PERFUSION.

PICTURE 13: CLINICAL EXAMINATION OF REVERSE SURAL ARTERY FLAP SHOWING ABSENT PIN PRICK, INDICATING ARTERIAL INSUFFICIENCY



PICTURE 14: FLIR PICTOGRAM SHOWS ABSENCE OF BLUE SPOTS (FALSE NEGATIVE ESULTS)

PICTURE 15: POST OPERATIVE CLINICAL PICTURE OF PECTORALIS MAJOR MYOCUTANEOUS FLAP SHOWING HEALTHY FLAP

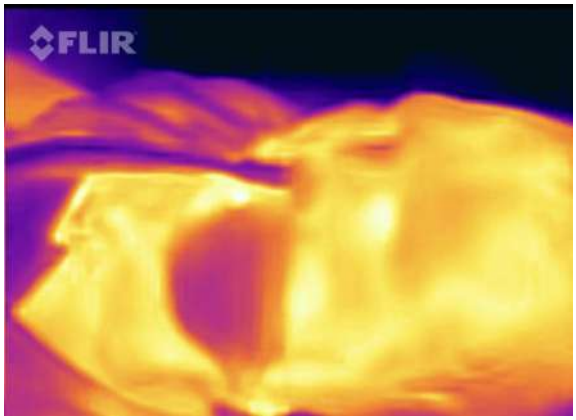


PICTURE 16: FLIR PICTOGRAM SHOWS PRESENCE OF BLUE SPOTS (FALSE POSITIVE RESULTS)

PICTURE 17: CLINICAL PICTURE OF GROIN FLAP INDICATING A HEALTHY FLAP

PICTURE 18: FLIR PICTOGRAM SHOWING WHITE AND BRIGHT YELLOW SPOTS (FALSE POSITIVE)

PICTURE 19: POST OPERATIVE CLINICAL PICTURE OF PECTORALIS MAJOR MYOCUTANEOUS FLAP SHOWING HEALTHY FLAP



PICTURE 20: FLIR PICTOGRAM SHOWS PRESENCE OF BLUE SPOTS (FALSE POSITIVE RESULTS)

S.NO	INITIALS	MRD NO	AGE	AGE GROUP	SEX	DIAGNOSIS	SITE	FLAP NAME
1	SK	1146539	46	3	MALE	CA TONGUE	ORAL CAVITY	RADIAL ARTERY FREE FOREARM
2	PK	1470501	48	3	MALE	CA RIGHT BUCCAL MUCOSA + FLOOR MOUTH	ORAL CAVITY	PECTORALIS MAJOR MYOCUTANEOUS
3	JS	1419903	70	4	MALE	CA FLOOR OF MOUTH	ORAL CAVITY	PECTORALIS MAJOR MYOCUTANEOUS
4	SS	1459893	65	4	MALE	POST TRAUMA LEFT HAND DORSUM DEFECT	HAND	GROIN FLAP
5	JS	1442833	62	4	MALE	POST TRAUMA RIGHT HAND DORSUM DEFECT	HAND	GROIN FLAP
6	G	1450604	29	2	MALE	PILONIDAL SINUS	SACRAL REGION	LIMBERS FLAP
7	AK	1433792	23	2	MALE	POST TRAUMA LEG DEFECT	LEG	BIPEDICLE FLAP
8	SS	1467708	36	2	MALE	POST TRAUMA LEG DEFECT	LEG	CROSS LEG FLAP
9	SR	1495128	48	3	MALE	POST BURN LEFT HAND WOUND	HAND	GROIN FLAP
10	HS	1503868	23	2	MALE	POST MACHINE INJURY RIGHT MIDDLE FINGER DEFECT	MIDDLE FINGER RIGHT	CROSS FINGER FLAP
11	H	1502642	6	1	MALE	POST TRAUMA LEG DEFECT	LEG	CROSS LEG FLAP
12	L	1504041	27	2	MALE	POST TRAUMA RIGHT HAND DORSUM DEFECT	HAND	GROIN FLAP
13	AM	777172	61	4	MALE	CA LIP	LIP	FOREHEAD FLAP
14	PS	1500752	28	2	MALE	POST BURN SCALP +FOREHEAD DEFECT	SCALP AND FOREHEAD	FREE ALT FLAP
15	I	1510521	35	2	MALE	POST TRAUMA FOOT DEFECT	FOOT	FREE LATISMIS DORSI FLAP
16	R	1517115	52	3	MALE	POST TRAUMA FINGER DEFECT	FINGER	CROSS FINGER FLAP
17	JK	1537889	14	1	FEMALE	POST TRAUMA INDEX FINGER DEFECT	FINGER	THENAR FLAP
18	A	1539268	59	3	MALE	CA BUCCAL MUCOSA	ORAL CAVITY	RADIAL ARTERY FREE FOREARM
19	SS	1525845	34	2	MALE	POST ELECTRIC BURN RIGHT WRIST DEFECT	WRIST	FREE ALT FLAP
20	N	1508296	3	1	MALE	POST RSA LEG WOUND	LEG	CROSS LEG FLAP
21	A	1458722	40	2	MALE	CA TONGUE	ORAL CAVITY	RADIAL ARTERY FREE FOREARM
22	B	1513410	34	2	MALE	OPEN FOOT WOUND	FOOT	REVERSE SURAL ARTERY FLAP
23	J	1514131	20	1	MALE	POST BURN RIGHT HAND DEFECT	HAND	GROIN FLAP
24	R	1564320	64	4	FEMALE	POST PAROTIDECTMY FACIAL DEFECT	FACE	TRANSPOSITION FLAP
25	CS	1042710	48	3	MALE	POST BASAL CELL CA FACE DEFECT	FACE	V-Y ADVANCEMENT FLAP
26	PK	1180762	67	4	MALE	CA LEFT BUCCAL MUCOSA	ORAL CAVITY	RADIAL ARTERY FREE FOREARM
27	J	1464231	42	3	MALE	POST TRAUMA RIGHT MIDDLE FINGER DEFECT	FINGER	CROSS FINGER FLAP
28	RP	1517115	52	3	MALE	MACHINE CUT RIGHT MIDDLE FINGER INJURY	FINGER	CROSS FINGER FLAP
29	KK	1444673	27	2	MALE	PILONIDAL SINUS INTERGLUTEAL DEFECT	SACROANAL	LIMBERS FLAP
30	RK	1548545	38	2	MALE	POST SARCOMA LEFT HAND DEFECT	HAND	GROIN FLAP
31	G	1602206	52	3	MALE	POST TRAUMA NASAL DEFECT	FACE	PARMEDIAN FOREHEAD FLAP
32	NA	1601855	52	3	MALE	POST ELECTRIC BURN RIGHT LEG DEFECT	LEG	INFERIORLY BASED TRANSPOSITION FLAP
33	NA	1661855	52	3	MALE	POST ELECTRIC BURN CONTACT WOUND	RIGHT CHEST WALL	LIMBERS FLAP
34	N	1592054	17	1	MALE	BILATERAL SACRAL GRADE 4 BEDSORE	SACRUM	L AND V-Y POSTERIOR THIGH ADVANCEMENT FLAP
35	N	1592054	17	1	MALE	BILATERAL SACRAL GRADE 4 BEDSORE	SACRUM	PEDICLED GROIN FLAP
36	RK	1548545	38	2	MALE	POST SARCOMA LEFT HAND DEFECT	HAND	FREE ALT FLAP
37	VK	499098	60	3	MALE	SCC LIP	FACE	FREE RADIAL ARTERY FOREARM FLAP
38	AS	1666714	45	3	MALE	POST ELECTRIC BURN CONTACT WOUND	Right HAND	GROIN FLAP
39	J	1715066	35	2	MALE	POST TRAUMA LEG DEFECT	LEG	CROSS LEG FLAP
40	GR	1688913	60	3	FEMALE	CA BUCCAL MUCOSA	ORAL CAVITY	FREE ALT FLAP

S.NO	INITIALS	MRD NO	FLAP EVALUATION AT 0 HR_COLOUR	CAP REFILL	BLEED	TEMP	LUATION AT 1 HR_	CAP REFILL	BLEED	TEMP	FLAP EVALUATION AT 3RD HOUR_COLOUR	CAP REFILL	BLEED	TEMP	FLAP EVALUATION AT 6 HRS_COLOUR	CAP REFILL
1	SK	1146539	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
2	PK	1470501	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
3	JS	1419903	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
4	SS	1459893	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
5	JS	1442833	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
6	G	1450604	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
7	AK	1433792	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
8	SS	1467708	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
9	SR	1495128	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
10	HS	1503868	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
11	H	1502642	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
12	L	1504041	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
13	AM	777172	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
14	PS	1500752	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
15	I	1510521	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	BLUISH	PROLONGED
16	R	1517115	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
17	JK	1537889	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
18	A	1539268	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
19	SS	1525845	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
20	N	1508296	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
21	A	1458722	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
22	B	1513410	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
23	J	1514131	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
24	R	1564320	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
25	CS	1042710	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
26	PK	1180762	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
27	J	1464231	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
28	RP	1517115	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
29	KK	1444673	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
30	RK	1548545	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
31	G	1602206	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
32	NA	1601855	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
33	NA	1661855	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
34	N	1592054	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
35	N	1592054	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
36	RK	1548545	N	N	MIXED	N	N	N	MIXED	N	N	N	MIXED	N	N	N
37	VK	499098	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
38	AS	1666714	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
39	J	1715066	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
40	GR	1688913	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N

S.NO	INITIALS	MRD NO	BLEED	TEMP	FLAP EVALUATION AT 12 HRS_COLOUR	CAP REFILL	BLEED	TEMP	FLAP EVALUATION AT 24 HRS_COLOUR	CAP REFILL	BLEED	TEMP
1	SK	1146539	ART	N	N	N	ART	N	N	N	ARTERIAL	N
2	PK	1470501	ART	N	N	N	DELAYED ARTERIAL	N	N	N	DELAYED ARTERIAL	N
3	JS	1419903	ART	N	N	N	ART	N	N	N	ARTERIAL	N
4	SS	1459893	ART	N	N	N	ART	N	N	N	ARTERIAL	N
5	JS	1442833	ART	N	N	N	ART	N	N	N	ARTERIAL	N
6	G	1450604	ART	N	N	N	ART	N	N	N	ARTERIAL	N
7	AK	1433792	ART	N	N	N	ART	N	N	N	ARTERIAL	N
8	SS	1467708	ART	N	N	N	ART	N	N	N	ARTERIAL	N
9	SR	1495128	ART	N	N	N	ART	N	N	N	ARTERIAL	N
10	HS	1503868	ART	N	N	N	ART	N	N	N	ARTERIAL	N
11	H	1502642	ART	N	N	N	ART	N	N	N	ARTERIAL	N
12	L	1504041	ART	N	N	N	ART	N	N	N	ARTERIAL	N
13	AM	777172	ART	N	N	N	ART	N	N	N	ARTERIAL	N
14	PS	1500752	ART	N	N	N	ART	N	N	N	ARTERIAL	N
15	I	1510521	VENOUS	INCREASE	BLUISH	PROLONGED	VENOUS	INCREASE	BLUE	PROLONGED	VENOUS	INCREASE
16	R	1517115	ART	N	N	N	ART	N	N	N	ARTERIAL	N
17	JK	1537889	ART	N	N	N	ART	N	N	N	ARTERIAL	N
18	A	1539268	ART	N	N	N	ART	N	N	N	ARTERIAL	N
19	SS	1525845	ART	N	N	N	ART	N	N	N	ARTERIAL	N
20	N	1508296	ART	N	N	N	ART	N	N	N	ARTERIAL	N
21	A	1458722	ART	N	N	N	ART	N	N	N	ARTERIAL	N
22	B	1513410	ART	N	N	N	ART	N	N	N	ARTERIAL	N
23	J	1514131	ART	N	N	N	ART	N	N	N	ARTERIAL	N
24	R	1564320	ART	N	N	N	ART	N	N	N	ARTERIAL	N
25	CS	1042710	ART	N	N	N	ART	N	N	N	ARTERIAL	N
26	PK	1180762	ART	N	N	N	ART	N	N	N	ARTERIAL	N
27	J	1464231	ART	N	N	N	ART	N	N	N	ARTERIAL	N
28	RP	1517115	ART	N	N	N	ART	N	N	N	ARTERIAL	N
29	KK	1444673	ART	N	N	N	ART	N	N	N	ARTERIAL	N
30	RK	1548545	ART	N	N	N	ART	N	N	N	ARTERIAL	N
31	G	1602206	ART	N	N	N	ART	N	N	N	ARTERIAL	N
32	NA	1601855	ART	N	N	N	ART	N	N	N	ARTERIAL	N
33	NA	1661855	ART	N	N	N	ART	N	N	N	ARTERIAL	N
34	N	1592054	ART	N	N	N	ART	N	N	N	ARTERIAL	N
35	N	1592054	ART	N	N	N	ART	N	N	N	ARTERIAL	N
36	RK	1548545	VENOUS	N	N	PROLONGED	VENOUS	N	BLUE	PROLONGED	VENOUS	N
37	VK	499098	ART	N	N	N	ART	N	N	N	ARTERIAL	N
38	AS	1666714	ART	N	N	N	ART	N	N	N	ARTERIAL	N
39	J	1715066	ART	N	N	N	ART	N	N	N	ARTERIAL	N
40	GR	1688913	ART	N	N	N	ART	N	N	N	ARTERIAL	N

S.NO	INITIALS	MRD NO	FLAP EVALUATION AT 48 HRS_COLOUR	CAP REFILL	BLEED	TEMP	FLIR CAMERA PICTOGRAM_0HR	1HR	3 HR	6 HR	12 HR	24 HR
1	SK	1146539	N	N	ARTERIAL	N	N	N	N	N	N	N
2	PK	1470501	N	N	DELAYED ARTERIAL	N	N	N	BLUE SPOTS	BLUE SPOTS	BLUE SPOTS	N
3	JS	1419903	N	N	ARTERIAL	N	N	N	N	N	N	N
4	SS	1459893	N	N	ARTERIAL	N	N	N	N	N	N	N
5	JS	1442833	N	N	ARTERIAL	N	N	N	N	N	N	N
6	G	1450604	N	N	ARTERIAL	N	N	N	N	N	N	N
7	AK	1433792	N	N	ARTERIAL	N	N	N	N	N	N	N
8	SS	1467708	N	N	ARTERIAL	N	N	N	N	N	N	N
9	SR	1495128	N	N	ARTERIAL	N	N	N	N	N	N	N
10	HS	1503868	N	N	ARTERIAL	N	N	N	N	N	N	N
11	H	1502642	N	N	ARTERIAL	N	N	N	N	N	N	N
12	L	1504041	N	N	ARTERIAL	N	N	N	N	N	N	N
13	AM	777172	N	N	ARTERIAL	N	N	N	N	N	N	N
14	PS	1500752	N	N	ARTERIAL	N	N	N	N	N	N	N
15	I	1510521	BLUISH	PROLONGED	VENOUS	Cold	N	N	WHITE	WHITE AND YELLOW	WHITE	WHITE
16	R	1517115	N	N	ARTERIAL	N	N	N	N	N	N	N
17	JK	1537889	N	N	ARTERIAL	N	N	N	N	N	N	N
18	A	1539268	N	N	ARTERIAL	N	N	N	N	N	N	N
19	SS	1525845	N	N	ARTERIAL	N	N	N	N	N	N	N
20	N	1508296	N	N	ARTERIAL	N	N	N	N	N	N	N
21	A	1458722	N	N	ARTERIAL	N	N	N	N	N	N	N
22	B	1513410	N	N	ARTERIAL	N	N	N	N	N	N	N
23	J	1514131	N	N	ARTERIAL	N	N	N	N	N	N	N
24	R	1564320	N	N	ARTERIAL	N	N	N	N	N	N	N
25	CS	1042710	N	N	ARTERIAL	N	N	N	N	N	N	N
26	PK	1180762	N	N	ARTERIAL	N	N	N	N	N	N	N
27	J	1464231	N	N	ARTERIAL	N	N	N	N	N	N	N
28	RP	1517115	N	N	ARTERIAL	N	N	N	N	N	N	N
29	KK	1444673	N	N	ARTERIAL	N	N	N	N	N	N	N
30	RK	1548545	N	N	ARTERIAL	N	N	N	N	N	N	N
31	G	1602206	N	N	ARTERIAL	N	N	N	N	N	N	N
32	NA	1601855	N	N	ARTERIAL	N	N	N	N	N	N	N
33	NA	1661855	N	N	ARTERIAL	N	N	N	N	N	N	N
34	N	1592054	N	N	ARTERIAL	N	N	N	N	N	N	N
35	N	1592054	N	N	ARTERIAL	N	N	N	N	N	N	N
36	RK	1548545	ABSENT	PROLONGED	VENOUS	COLD	N	N	N	N	WHITE	WHITE
37	VK	499098	N	N	ARTERIAL	N	N	N	N	N	N	N
38	AS	1666714	N	N	ARTERIAL	N	N	N	N	N	N	N
39	J	1715066	N	N	ARTERIAL	N	N	N	N	N	N	N
40	GR	1688913	N	N	ARTERIAL	N	N	N	N	N	N	N

S.NO	INITIALS	MRD NO	48 HR	INTER REQ	DUR AFTER SX	NECROSIS SIGN	FINAL OUTCOME_SURVIVAL	VENOUS INSUFF	ARTERIAL INSUFF	NECROSIS	COMPLICATION
1	SK	1146539	N	NO	NO	NO	YES	NO	NO	NO	NO
2	PK	1470501	N	SUTURE REMOVAL WITH HEPARIN SPRAY	NO	NO	YES	NO	YES	NO	YES
3	JS	1419903	N	NO	NO	NO	YES	NO	NO	NO	NO
4	SS	1459893	N	NO	NO	NO	YES	NO	NO	NO	NO
5	JS	1442833	N	NO	NO	NO	YES	NO	NO	NO	NO
6	G	1450604	N	NO	NO	NO	YES	NO	NO	NO	NO
7	AK	1433792	N	NO	NO	NO	YES	NO	NO	NO	NO
8	SS	1467708	N	NO	NO	NO	YES	NO	NO	NO	NO
9	SR	1495128	N	NO	NO	NO	YES	NO	NO	NO	NO
10	HS	1503868	N	NO	NO	NO	YES	NO	NO	NO	NO
11	H	1502642	N	NO	NO	NO	YES	NO	NO	NO	NO
12	L	1504041	N	NO	NO	NO	YES	NO	NO	NO	NO
13	AM	777172	N	NO	NO	NO	YES	NO	NO	NO	NO
14	PS	1500752	N	NO	NO	NO	YES	NO	NO	NO	NO
15	I	1510521	BLUE	OPENING SUTURE	8 hrs	YES	NO	YES	NO	YES	YES
16	R	1517115	N	NO	NO	NO	YES	NO	NO	NO	NO
17	JK	1537889	N	NO	NO	NO	YES	NO	NO	NO	NO
18	A	1539268	N	NO	NO	NO	YES	NO	NO	NO	NO
19	SS	1525845	N	NO	NO	NO	YES	NO	NO	NO	NO
20	N	1508296	N	NO	NO	NO	YES	NO	NO	NO	NO
21	A	1458722	N	NO	NO	NO	YES	NO	NO	NO	NO
22	B	1513410	N	NO	NO	NO	YES	NO	NO	NO	NO
23	J	1514131	N	NO	NO	NO	YES	NO	NO	NO	NO
24	R	1564320	N	NO	NO	NO	YES	NO	NO	NO	NO
25	CS	1042710	N	NO	NO	NO	YES	NO	NO	NO	NO
26	PK	1180762	N	NO	NO	NO	YES	NO	NO	NO	NO
27	J	1464231	N	NO	NO	NO	YES	NO	NO	NO	NO
28	RP	1517115	N	NO	NO	NO	YES	NO	NO	NO	NO
29	KK	1444673	N	NO	NO	NO	YES	NO	NO	NO	NO
30	RK	1548545	N	NO	NO	NO	YES	NO	NO	NO	NO
31	G	1602206	N	NO	NO	NO	YES	NO	NO	NO	NO
32	NA	1601855	N	NO	NO	NO	YES	NO	NO	NO	NO
33	NA	1661855	N	NO	NO	NO	YES	NO	NO	NO	NO
34	N	1592054	N	NO	NO	NO	YES	NO	NO	NO	NO
35	N	1592054	N	NO	NO	NO	YES	NO	NO	NO	NO
36	RK	1548545	WHITE	Scratch SKIN Paddle AND HEparin SPRAY	10 hours	YES	NO	YES	NO	YES	YES
37	VK	499098	N	NO	No	NO	YES	NO	NO	NO	NO
38	AS	1666714	N	NO	No	NO	YES	NO	NO	NO	NO
39	J	1715066	N	NO	No	NO	YES	NO	NO	NO	NO
40	GR	1688913	N	NO	No	NO	YES	NO	NO	NO	NO

S.NO	INITIALS	MRD NO	AGE	AGE GROUP	SEX	DIAGNOSIS	SITE	FLAP NAME
41	NS	1659356	25	2	MALE	Post machine injury scalp defect	SCALP	FREE ALT FLAP
42	VK	1623406	47	3	MALE	Left LEG DEFECT	LEG	FREE ALT FLAP
43	V	1635231	18	1	MALE	POST MACHINE INJURY FINGER DEFECT MIDDLE FINGER DEFECT	FINGER	GROIN FLAP
44	SK	1657690	19	1	MALE	POST TRAUMA HEEL DEFECT	FOOT	REVERSE SURAL ARTERY FLAP
45	G	1672638	29	2	MALE	Post BURN HAND DEFECT	HAND	GROIN FLAP
46	DD	168903	70	4	FEMALE	SCC DORSUM OF NOSE	FACE	FREE RADIAL ARTERY FOREARM FLAP
47	BS	1677097	31	2	MALE	POST ELECTRIC BURN WRIST DEFECT	WRIST	FREE ALT FLAP
48	KR	1602796	57	3	FEMALE	SCC LOWER LIP	FACE	FREE RADIAL ARTERY FOREARM FLAP
49	R	1700684	30	2	MALE	POST BURN NECK DEFECT	NECK	PECTORALIS MAJOR MYOCUTANEOUS
50	SS	168177	52	3	MALE	POST TRAUMA LEG DEFECT	LEG	CROSS LEG FLAP
51	V	1728587	42	3	MALE	POST TRAUMA LEG DEFECT	LEG	TRANSPOSITION FLAP
52	BS	1623612	64	4	MALE	SCC LIP	FACE	FREE RADIAL ARTERY FOREARM FLAP
53	GS	1774006	40	2	MALE	SCC LIP	FACE	FREE RADIAL ARTERY FOREARM FLAP
54	PNS	1771193	69	4	MALE	SCC BUCCAL REGION	FACE	FREE RADIAL ARTERY FOREARM FLAP
55	R		37	2	MALE	HEEL DEFECT	FOOT	REVERSE SURAL ARTERY FLAP
56	MG	1610907	24	2	MALE	Hand	HAND	GROIN FLAP
57	HBS	1632711	39	2	MALE	HEEL DEFECT	FOOT	REVERSE SURAL ARTERY FLAP
58	J	1618730	59	3	MALE	Left ca buccal region	FACE	PECTORALIS MAJOR MYOCUTANEOUS
59	KK	1455665	56	3	MALE	POST machine injury dorsum of hand defect	HAND	GROIN FLAP
60	SK	1603753	50	3	MALE	CA BUCCAL MUCOSA	FACE	RADIAL ARTERY FREE FOREARM
61	AS	1597027	48	3	MALE	Ca left alveolus	FACE	RADIAL ARTERY FREE FOREARM
62	RKM	1578855	70	4	MALE	POST TRAUMA LEG DEFECT	LEG	TRANSPOSITION FLAP
63	M	1565455	55	3	MALE	POST TRAUMA LEG DEFECT	LEG	CROSS LEG FLAP
64	D	1179770	63	4	MALE	CA BUCCAL MUCOSA	FACE	PECTORALIS MAJOR MYOCUTANEOUS
65	BS	1557383	25	2	MALE	POST TRAUMA LEG DEFECT	LEG	CROSS LEG FLAP
66	HK	1558181	47	3	MALE	POST TRAUMA LEG DEFECT	LEG	TRANSPOSITION FLAP
67	D	80426	26	2	MALE	POST TRAUMA LEG DEFECT	LEG	TRANSPOSITION FLAP
68	H	1546187	38	2	MALE	POST TRAUMA LEG DEFECT	LEG	TRANSPOSITION FLAP
69	G	1514949	25	2	MALE	POST BURN HAND DEFECT	HAND	GROIN FLAP
70	P	1500757	28	2	MALE	POST BURN SCALP +FOREHEAD DEFECT	SCALP	FREE LATISMIS DORSI FLAP

S.NO	INITIALS	MRD NO	FLAP EVALUATION AT 0 HR_COLOUR	CAP REFILL	BLEED	TEMP	LUATION AT 1 HR_	CAP REFILL	BLEED	TEMP	FLAP EVALUATION AT 3RD HOUR_COLOUR	CAP REFILL	BLEED	TEMP	FLAP EVALUATION AT 6 HRS_COLOUR	CAP REFILL
41	NS	1659356	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	PROLONGED
42	VK	1623406	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
43	V	1635231	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
44	SK	1657690	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
45	G	1672638	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
46	DD	168903	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
47	BS	1677097	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
48	KR	1602796	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
49	R	1700684	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
50	SS	168177	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
51	V	1728587	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
52	BS	1623612	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
53	GS	1774006	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
54	PNS	1771193	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
55	R		N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
56	MG	1610907	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
57	HBS	1632711	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
58	J	1618730	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
59	KK	1455665	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
60	SK	1603753	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
61	AS	1597027	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
62	RKM	1578855	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
63	M	1565455	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
64	D	1179770	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
65	BS	1557383	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
66	HK	1558181	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
67	D	80426	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
68	H	1546187	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
69	G	1514949	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N
70	P	1500757	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N	ARTERIAL	N	N	N

S.NO	INITIALS	MRD NO	BLEED	TEMP	FLAP EVALUATION AT 12 HRS_COLOUR	CAP REFILL	BLEED	TEMP	FLAP EVALUATION AT 24 HRS_COLOUR	CAP REFILL	BLEED	TEMP
41	NS	1659356	ABSENT	N	N	N	ART	N	N	PROLONGED	ABSENT	COLD
42	VK	1623406	ART	N	N	N	ART	N	N	N	ARTERIAL	N
43	V	1635231	ART	N	N	N	ART	N	N	N	ARTERIAL	N
44	SK	1657690	ART	N	N	N	VENOUS	N	N	N	VENOUS	N
45	G	1672638	ART	N	N	N	ART	N	N	N	ARTERIAL	N
46	DD	168903	ART	N	N	N	ART	N	N	N	ARTERIAL	N
47	BS	1677097	ART	N	N	N	ART	N	N	N	ARTERIAL	N
48	KR	1602796	ART	N	N	N	ART	N	N	N	ARTERIAL	N
49	R	1700684	ART	N	N	N	ART	N	N	N	ARTERIAL	N
50	SS	168177	ART	N	N	N	ART	N	N	N	ARTERIAL	N
51	V	1728587	ART	N	MARGINAL BLACKENING	N	VENOUS	N	BLACKISH DISCOLOURATION	N	VENOUS	COLD
52	BS	1623612	ART	N	N	N	ART	N	N	N	ARTERIAL	N
53	GS	1774006	ART	N	N	N	ART	N	N	N	ARTERIAL	N
54	PNS	1771193	ART	N	N	N	ART	N	N	N	ARTERIAL	N
55	R		ART	N	N	N	ART	N	N	N	ARTERIAL	N
56	MG	1610907	ART	N	N	N	DELAYED ARTERIAL	N	N	PROLONGED	ABSENT	COLD
57	HBS	1632711	ART	N	N	N	ART	N	N	N	ARTERIAL	N
58	J	1618730	ART	N	N	N	ART	N	N	N	ARTERIAL	N
59	KK	1455665	ART	N	N	N	ART	N	N	N	ARTERIAL	N
60	SK	1603753	ART	N	N	N	ART	N	N	N	ARTERIAL	N
61	AS	1597027	ART	N	N	N	ART	N	N	N	ARTERIAL	N
62	RKM	1578855	ART	N	N	N	ART	N	N	N	ARTERIAL	N
63	M	1565455	ART	N	N	N	ART	N	N	N	ARTERIAL	N
64	D	1179770	ART	N	N	N	ART	N	N	N	ARTERIAL	N
65	BS	1557383	ART	N	N	N	ART	N	N	N	ARTERIAL	N
66	HK	1558181	ART	N	N	N	ART	N	N	N	ARTERIAL	N
67	D	80426	ART	N	N	N	ART	N	N	N	ARTERIAL	N
68	H	1546187	ART	N	N	N	ART	N	N	N	ARTERIAL	N
69	G	1514949	ART	N	N	N	ART	N	N	N	ARTERIAL	N
70	P	1500757	ART	N	N	N	ART	N	N	N	ARTERIAL	N

S.NO	INITIALS	MRD NO	FLAP EVALUATION AT 48 HRS_COLOUR	CAP REFILL	BLEED	TEMP	FLIR CAMERA PICTOGRAM_0HR	1HR	3 HR	6 HR	12 HR	24 HR
41	NS	1659356	N	PROLONGED	ABSENT	COLD	N	N	BLUE SPOTS	BLUE SPOTS	N	BLUE
42	VK	1623406	N	N	ARTERIAL	N	N	N	N	N	N	N
43	V	1635231	N	N	ARTERIAL	N	N	N	N	N	N	N
44	SK	1657690	N	N	VENOUS	N	N	N	N	N	N	N
45	G	1672638	N	N	ARTERIAL	N	N	N	N	N	N	BLUE
46	DD	168903	N	N	ARTERIAL	N	N	N	N	N	N	N
47	BS	1677097	N	N	ARTERIAL	N	N	N	N	N	N	N
48	KR	1602796	N	N	ARTERIAL	N	N	N	N	N	N	N
49	R	1700684	N	N	ARTERIAL	N	N	N	N	N	N	N
50	SS	168177	N	N	ARTERIAL	N	N	N	N	N	N	N
51	V	1728587	Discolouration	PROLONGED	VENOUS	N	N	N	N	N	N	N
52	BS	1623612	N	N	ARTERIAL	N	N	N	N	N	N	N
53	GS	1774006	N	N	ARTERIAL	N	N	N	N	N	N	N
54	PNS	1771193	N	N	ARTERIAL	N	N	N	N	N	N	N
55	R		N	N	ARTERIAL	N	N	N	N	N	N	N
56	MG	1610907	PALE	PROLONGED	ABSENT	COLD	N	N	N	N	N	N
57	HBS	1632711	N	N	ARTERIAL	N	N	N	N	N	N	N
58	J	1618730	N	N	ARTERIAL	N	N	N	N	N	N	WHITE
59	KK	1455665	N	N	ARTERIAL	N	N	N	N	N	WHITE	WHITE
60	SK	1603753	N	N	ARTERIAL	N	N	N	N	N	N	N
61	AS	1597027	N	N	ARTERIAL	N	N	N	N	N	N	N
62	RKM	1578855	N	N	ARTERIAL	N	N	N	N	N	N	N
63	M	1565455	N	N	ARTERIAL	N	N	N	N	N	N	N
64	D	1179770	N	N	ARTERIAL	N	N	N	N	WHITE	WHITE	WHITE
65	BS	1557383	N	N	ARTERIAL	N	N	N	N	N	N	N
66	HK	1558181	N	N	ARTERIAL	N	N	N	N	N	N	N
67	D	80426	N	N	ARTERIAL	N	N	N	N	N	N	N
68	H	1546187	N	N	ARTERIAL	N	N	N	N	N	N	N
69	G	1514949	N	N	ARTERIAL	N	N	N	N	N	N	N
70	P	1500757	N	N	ARTERIAL	N	N	N	N	N	N	N

S.NO	INITIALS	MRD NO	48 HR	INTER REQ	DUR AFTER SX	NECROSIS SIGN	FINAL OUTCOME_SURVIVAL	VENOUS INSUFF	ARTERIAL INSUFF	NECROSIS	COMPLICATION
41	NS	1659356	BLUE	EXPLORATION AT 8 HRS WITH ARTERIAL THROMECTOMY THROMBECTOMY AT 12 hrs	8 hrs	YES	NO	NO	YES	YES	YES
42	VK	1623406	N	NO	No	NO	YES	NO	NO	NO	NO
43	V	1635231	N	NO	No	NO	YES	NO	NO	NO	NO
44	SK	1657690	N	SUTURE REMOVAL WITH HEPARIN SPRAY	12 hrs	NO	YES	NO	NO	NO	YES
45	G	1672638	BLUE	NO	No	NO	YES	NO	NO	NO	NO
46	DD	168903	N	NO	No	NO	YES	NO	NO	NO	NO
47	BS	1677097	N	NO	No	NO	YES	NO	NO	NO	NO
48	KR	1602796	N	NO	No	NO	YES	NO	NO	NO	NO
49	R	1700684	N	NO	No	NO	YES	NO	NO	NO	NO
50	SS	168177	N	NO	No	NO	YES	NO	NO	NO	NO
51	V	1728587	BLUE	SUTURE REMOVAL WITH HEPARIN SPRAY	12 hrs	YES	NO	YES	YES	YES	YES
52	BS	1623612	N	NO	No	NO	YES	NO	NO	NO	NO
53	GS	1774006	N	NO	No	NO	YES	NO	NO	NO	NO
54	PNS	1771193	N	NO	No	NO	YES	NO	NO	NO	NO
55	R		N	NO	No	NO	YES	NO	NO	NO	NO
56	MG	1610907	N	SUTURE REMOVAL AND INJ CLEXANE 12 holy sc	12 hrs	YES	NO	NO	YES	YES	YES
57	HBS	1632711	N	NO	No	NO	YES	NO	NO	NO	NO
58	J	1618730	WHITE	NO	No	NO	YES	NO	NO	NO	NO
59	KK	1455665	WHITE	NO	No	NO	YES	NO	NO	NO	NO
60	SK	1603753	N	NO	No	NO	YES	NO	NO	NO	NO
61	AS	1597027	N	NO	No	NO	YES	NO	NO	NO	NO
62	RKM	1578855	N	NO	No	NO	YES	NO	NO	NO	NO
63	M	1565455	N	NO	No	NO	YES	NO	NO	NO	NO
64	D	1179770	WHITE	NO	No	NO	YES	NO	NO	NO	NO
65	BS	1557383	N	NO	No	NO	YES	NO	NO	NO	NO
66	HK	1558181	N	NO	No	NO	YES	NO	NO	NO	NO
67	D	80426	N	NO	No	NO	YES	NO	NO	NO	NO
68	H	1546187	N	NO	No	NO	YES	NO	NO	NO	NO
69	G	1514949	N	NO	No	NO	YES	NO	NO	NO	NO
70	P	1500757	N	NO	No	NO	YES	NO	NO	NO	NO

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The Principal
Dayanand Medical College & Hospital
Ludhiana

Subject:: Approval of Plan of Thesis.

This is to inform you that the Faculty of Medical Sciences in its meeting held on 25.09.2023 has approved the plan of thesis of **Ojassvi Rishi**, a student of your college for **MCh Plastic & Reconstructive Surgery** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis
Role of smartphone thermal imaging camera in post operative flap monitoring .

Supervisor
Dr. Rajinder K Mittal
Prof. & Head
Dept. of Plastic & Reconstructive Surgery

Co-Supervisor:-
Dr. Sheerin Shah
Assoc. Professor
Dept. of Plastic & Reconstructive Surgery

The student may submit the thesis in triplicate alongwith the plan in triplicate also, to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She may be directed to attach a photocopy of this letter with the forwarding letter while submitting thesis in the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic, if any.

Controller of Examinations

Note :

1. *If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.*

ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

M.Ch

IN

PLASTIC AND RECONSTRUCTIVE SURGERY

OF THE

BABA FARID UNIVERSITY OF HEALTH SCIENCES
FARIDKOT

OCTOBER, 2022

DR. OJASSVI RISHI

DEPARTMENT OF PLASTIC AND RECONSTRUCTIVE SURGERY
DAYANAND MEDICAL COLLEGE & HOSPITAL
LUDHIANA

ABSTRACT OF PLAN OF THESIS

Title	ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING
For the degree of	M.Ch Plastic and Reconstructive Surgery
Name of the candidate	Dr. Ojassvi Rishi
Supervisor	Dr. Rajinder K Mittal, Professor & Head, Department of Plastic and Reconstructive Surgery, DMCH, Ludhiana
Co-supervisor	Dr. Sheerin Shah, Associate Professor, Department of Plastic and Reconstructive Surgery , DMCH, Ludhiana
Institution	Dayanand Medical College & Hospital, Ludhiana
University	Baba Farid University of Health Sciences, Faridkot

Introduction: Careful Monitoring of flaps in post operative period is important for flap survival , immediate intervention increases salvage rate.Clinical assessment is considered the gold standard method but it depends on the clinical experience of the health care worker. Among the new tools , the use of smartphone thermal imaging is a more objective, convinient as well as a contactless and affordable method of flap monitoring.

Aim of Study: To determine the role of smartphone thermal imaging camera in monitoring of flap in the post operative period.

Materials & Methods: A prospective study will be conducted on all patients who undergo flap surgery (both pedicled and free flap) in Department of Plastic and Reconstructive Surgery , Dayanand medical college and Hospital, Ludhiana from November 2022 to April 2024.. After flap surgery, the thermal image using FLIR smartphone camera will be taken at 0,1,3,6,12,24 and 48 hours after surgery where 0 is immediately post operative time. The image will also be obtained whenever flap showed any signs of vascular compromise in between these time intervals. Two groups will be made :

Group1: Flaps with no post operative complications

Group2: Flap with post operative complications(signs of vascular compromise, necrosis, need of any surgical intervention).

Flap vascularity will be assessed by temperature gradient colour coding of thermal image taking the clinical assessment as gold standard. Sensitivity and specificity of the thermal camera will be calculated.

Clinical Significance: To determine the role of smartphone thermal imaging camera in monitoring of flap in the post operative period

Keywords: Flap monitoring, thermal imaging, contactless, affordable

(Signature)	(Signature)	(Signature)	(Signature)
Candidate	Co-Supervisor	Supervisor	Principal

CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING"** exist in the Department of Plastic and Reconstructive surgery, DMC&H, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis is genuine and is collected by the candidate herself under our supervision and guidance.

Supervisor

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Place : _____

Date : _____

APPROVAL PROFORMA
BY RESEARCH & ETHICAL COMMITTEE
DAYANAND MEDICAL COLLEGE & HOSPITAL, LUDHIANA

Name of candidate	Dr. Ojassvi Rishi
Department	Plastic and Reconstructive Surgery
Topic of Thesis	ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING
Likely date of appearing in PG examination	May/June- 2024
Date of enrollment	28.12.2020
Name of Head of Department	Dr. Rajinder K Mittal
1) Supervisor **2) Co-Supervisor**	Dr. Rajinder Mittal Dr. Sheerin Shah
Signature of Members of Research Committee with Stamp	**Signature of Members of Ethics Committee with Stamp**
Dr. Harpreet Kaur (Professor & Head, Pathology)	Mr. R K Sharma (Legal Expert)
Dr. Jaspal Singh (Professor & Head, Surgery)	Dr. Ramit Mahajan (Associate Professor, Gastroenterology)
Dr. Dinesh Gupta (Professor & Head, Medicine)	Dr. Anu Sharma (Professor, Anatomy)
Dr. Sandeep Kaushal (Dean Academics & Professor & Head, Pharmacology)	Dr. Sandeep Kaushal (Dean Academics & Professor & Head, Pharmacology)
Dr. Gurpreet S Wander (Vice Principal)	Dr. Gurpreet S Wander (Vice Principal & Professor & Head, Cardiology)
	Dr. Gagandeep Singh (Secretary, Ethics Committee Professor & Head, Neurology)

Approved: Yes / No

Dr. Sandeep Puri
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Research Committee

Approved: Yes / No

Prof. Arvind Malhotra
Chairperson
Ethics Committee
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Ethics Committee

BABA FARID UNIVERSITY OF HEALTH SCIENCES, FARIDKOT

PROFORMA FOR REGISTRATION OF SUBJECT FOR DISSERTATION

1	NAME OF THE CANDIDATE AND ADDRESS	DR. OJASSVI RISHI
2	NAME OF THE INSTITUTE	DAYANAND MEDICAL COLLEGE AND HOSPITAL
3	COURSE OF STUDY AND SUBJECT	M.CH PLASTIC AND RECONSTRUCTIVE SURGERY
4	DATE OF ADMISSION TO COURSE	28.12.2020
5	TITLE OF THE TOPIC	ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING

6.0 BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR STUDY

A flap is a unit of tissue which is transferred from a donor to a recipient site with its blood supply.[1]

In today's era of reconstructive surgery, flaps are standard method of choice for management of complex defects. The free flap procedures have high success rate as reported to be around 95%.[2] Most of the flap failures are due to venous (54–57%) followed by arterial thrombosis (20–43%) and these also mostly within the 72 hours.[3-4] In post operative period, if the flap becomes compromised, it can be salvaged if immediate intervention is done. So, the most important steps in order to perform a successful flap surgery is the monitoring of the patient in the post operative period.[5]

There are various methods available for monitoring of flaps like clinical monitoring, infrared spectroscopy ,hand held and implantable Doppler and indocyanine green[6] With recent advancements in smartphone technologies, there start of breakthrough era of promising techniques for monitoring flaps.[7]

Clinical assessment is considered the gold standard method but it depends on the clinical experience of the health care worker. Among the new tools , the use of smartphone thermal imaging is a more objective, convinient as well as a contactless and affordable method of flap monitoring. Limited research has been done to determine the accuracy of the thermal imaging camera in the identification of flap viability postoperatively. The aim of this study was to use the utility of thermal imaging camera, as an adjunct to standard clinical methods used for postoperative flap monitoring.

6.2 REVIEW OF LITERATURE

Monitoring of flap in post operative period is very significant to a plastic and reconstructive surgeon. The flap survival (free as well as pedicled) is dependant not only upon the surgical technique along with experienced hands but also on monitoring of flaps in post operative period and timely decision to re-explore in addition the general condition of the patient.

Success rate of free flap is reported to be 95% or higher, but the major cause of tissue loss includes the problem of anastomosed artery or vein[8] And in general, more than arterial thrombosis venous compromise or congestion is more common as cause of flap failure. Other causes includes extrinsic compression or kinking. There are various methods available for monitoring of flaps like clinical monitoring, infrared spectroscopy ,hand held and implantable Doppler and indocyanine green[6] Clinical assessment is considered the gold standard method but it depends on the clinical experience of the health care worker But it is often too late when these clinical signs become apparent.[17] With recent advancements in smartphone technologies, there start of breakthrough era of promising techniques for monitoring flaps.[7]

Surface temperature measurement is one of the oldest techniques of post-operative free flap monitoring. Measuring temperature can be performed either by placing a sensor directly onto the skin or by measuring temperature through a contactless method.[9]

Thermal imaging technology converts infrared electromagnetic radiations to a pictorial format that are proportional to the temperature where different colours are specific for a temperature gradient. Overall, brighter images are produced with a default colour range from dark blue that represents the coolest body part to garish yellow or white that represent the hottest part. Different shades of red and orange show body parts with intermediate temperature levels.[10]

A thermographic camera (aka infrared camera or thermal imaging camera) uses infrared radiation to form an image. The operating wavelength of the thermal camera is 14,00 nm, which differs it from an ordinary light digital camera (wavelength of 400–700 nm).[11]

FLIR ONE® is a low cost imaging device that couples with micro-USB port of Android or lightening port of iOS smartphones. It uses a second light camera to capture still or moving real time image for comparison.[12]

Xavier et al. used a thermographic camera to map colour and temperature differences after ligation of the inferior superficial epigastric vessel of one side using the contralateral artery as a control in 20 rats. They found immediate disappearance of hot spot corresponding to the artery after ligation before skin showed any change of vascular compromise. Similarly, thermographic changes appeared after venous ligation before the macroscopic appearance of congestion.[13]

Flap monitoring study by Rabbani et at using thermal imaging camera stated diagnostic accuracy of thermal imaging camera as 96.43% with a sensitivity of 98.7%, specificity of 75%. The positive predictive value was found to be 97.4%, negative predictive value was 85.7%, the false-negative value was 14.3%, and the false-positive value was 2.6%.[9]

Khouri et al reviewed a large series of 600 free flaps where surface-temperature recording was the main method of monitoring used and a detailed temperature record was kept. The sensitivity of surface-temperature recording was documented as 98 percent with predictive value to be 75 percent, making it a simple, inexpensive, and highly reliable technique of free-flap monitoring.[14]

In 2015 Maren et al. conducted a study on monitoring of free flaps for oropharyngeal reconstruction by thermal imaging. They calculated the temperature differences and examined the thermal images in pre-operative, intra-operative (both pre-anastomosis and post-anastomosis)

and postoperative course and found significant temperature difference before and after vascular anastomosis of the flap. They used endoscopic infrared thermographic camera and relied more on temperature difference than the thermal image itself.[15]

In the study by hummelick et al flaps were assessed with indocyanine green fluorescence angiography as well as hourly clinical assessment of skin colour, turgor and capillary refill. Furthermore, thermal photographs were taken simultaneously with the FLIR One thermal camera smartphone module. These photographs were processed in MATLAB and evaluated on their additional value as an indicator for flap failure. Vascular compromise in free flaps can be distinguished by investigating relative temperature differences between the flap and reference skin.[16]

About 68 –75% flaps can be salvaged if the re-vascularisation is achieved within an hour of vascular insult.[18] Therefore, methods to monitor flaps for timely intervention needs to be studied. So this study aims to determine the role of thermal imaging smart phone camera in post operative flap monitoring.

6.3 AIMS AND OBJECTIVES-

- To determine the role of smartphone thermal imaging camera in monitoring of flap in the post operative period.

.

7.0 MATERIAL AND METHODS:

7.1 SOURCE OF DATA:

A prospective study will be conducted on all patients who undergo flap surgery (both pedicled and free flap) in department of Plastic and Reconstructive Surgery, Dayanand medical college and Hospital, Ludhiana from November 2022 to April 2024.

7.2 METHOD OF COLLECTION OF DATA

INCLUSION CRITERIA-

All patients who-

- Give informed consent to participate in this study
- Undergoes any flap surgery with assessable skin paddle

EXCLUSION CRITERIA-

- Patients who did not give consent.
- Patients with inaccessible flaps .

DURATION OF STUDY:

FLIR (FORWARD LOOKING INFRA RED) smartphone thermal imaging camera will be used. After inserting the thermal imaging camera into charging port (micro- USB port)of smart phone , the phone application will be selected. Camera will be used to obtain thermal image of the flap.

- The instructions to obtain the thermal pictogram will be followed as per the FLIR camera protocol. The viability of flap circulation will be noted according to temperature gradient colour coding taking bright orange, yellow and white as well perfused while dark orange , red blue or purple as poorly perfused or non perfused areas. The pictogram will be taken at

0,1,3,6,12,24 and 48 hours after surgery where 0 is immediately post operative time. Clinical assessment which includes colour of skin paddle, capillary refill , temperature, bleeding on pin prick will also be done at same time intervals.

Thermal pictogram will also be obtained whenever clinically flap will show any signs of vascular compromise.

Two groups will be made :

Group1: Flaps with no post operative complications.

Group2: Flap with post operative complications(signs of vascular compromise, necrosis, need of any surgical intervention).

Decision to intervene surgically will be based exclusively on clinical assessment.

OUTCOME

Flap vascularity will be assessed by temperature gradient colour coding of thermal image taking the clinical assessment as gold standard. Sensitivity and specificity of the thermal camera will be calculated .

STATISTICAL ANALYSIS

Continuous variables will be reported as mean (standard deviation) or median (interquartile range) depending on the distribution of data and frequency(percentage). Categorical variables will be described using absolute and relative frequencies and will be analyzed with a X2 test. All analyses will be conducted using SPSS (statistical package for the social science) SPSS 21version(SPSS Inc, Chicago, IL, USA) and will be two tailed, with $P<0.05$ as the level of significance.

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

No

7.4 HAS ETHICAL CLEARANCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Attached herewith

8. LIST OF REFERENCES

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PROFORMA

S. No. MRD No.

NAME AGE/SEX

FATHER'S/HUSBAND'S NAME

DIAGNOSIS

SITE OF RECONSTRUCTION:

FLAP NAME:

CLINICAL EVALUATION OF FLAP:

DURATION(HRS)	0	1	3	6	12	24	48
COLOUR							
CAPILLARY REFILL							
BLEEDING CHARACTERISTICS							
TEMPERATURE							
OUTCOME OF FLAP							

Thermal pictogram at same time intervals and also in between if any signs of vascular compromise.

INTERVENTION REQUIRED	**DURATION AFTER SURGERY (hrs)**	**SIGNS OF NECROSIS CLINICALLY AND ON THERMAL PICTOGRAM**

FINAL OUTCOME OF FLAP (Tick Appropriate)

FLAP SURVIVED	**VENOUS INSUFFICIENCY**	**ARTERIAL INSUFFICIENCY**	**FLAP NECROSIS**

Signature of Candidate Signature of Supervisor

INFORMED PATIENT CONSENT

Date: _____

I……..D/o, W/o, S/o **"ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING"** The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

……. ……
Signature of the Witness Signature of the patient

Name:

Signature of Candidate **Signature of Supervisor**

मरीज अनुमति फार्म

तिथि _____

मैं _____ पत्नी/पुत्र/पुत्री _____

निवासी _____

इस शोधकार्य **"ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING"** में भाग लेने के लिए सहमत हूँ। मैं इस शोधकार्य में भाग लेने के लिए अपनी स्वेच्छा से तैयार हूँ। मैं पुष्टि करता/करती हूँ की यह स्वीकृति देने के लिए मुझे कोई आर्थिक प्रलोभन नहीं दिया गया और न ही दबाव डाला गया है। मुझे इस शोधकार्य का उद्देश्य स्पष्ट कर दिया गया है और मुझे यह विश्वास है की यह विज्ञान और मानवता के लाभ के लिए है। मुझे इस शोधकार्य में होने वाले जोखिम के बारे में समझा दिया गया है और मेरी समझ में यह जोखिम बहुत मामुली है।

मैं इस शोधकार्य में भाग लेने के सम्बन्ध में किसी भी समय अपनी अस्वीकृति व्यक्त कर सकता/सकती हूँ और मेरे अस्वीकृति व्यक्त करने का मेरे इलाज पर कोई प्रभाव नहीं पड़ेगा।

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गवाह के हस्ताक्षर रोगी के हस्ताक्षर/अंगूठे का निशान

नाम: नाम:

_____

अन्वेषक के हस्ताक्षर

_____

विद्यार्थी के हस्ताक्षर

ਮਰੀਜ਼ ਰਜ਼ਾਮੰਦੀ ਫਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

“ROLE OF SMARTPHONE THERMAL IMAGING CAMERA IN POST OPERATIVE FLAP MONITORING” ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।
ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

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ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ ਮਰੀਜ਼ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____ ਮਿਤੀ_____

ਪਤਾ _____ ਪਤਾ _____

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ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

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ਸਿਖਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ